

Courses

Cognitive, Computational and Social Neurosciences

Academic Year 2019 - 2020

Advanced Methods for Complex Systems I

Abstract: This interdisciplinary course aims at introducing rigorous tools from statistical physics, information theory and probability theory to investigate real-world complex systems arising in different fields of research. First, some key aspects of complexity encountered in physical, biological, social, economic and technological systems will be reviewed. Then, emphasis will be put on the construction of theoretical models based on the concept of constrained randomness, i.e. the maximisation of the entropy subject to suitable constraints. This will lead to the introduction of maximum-entropy models that serve as mathematical benchmarks for the properties of highly heterogeneous complex systems. Special cases of interest include statistical ensembles of complex networks and of multivariate time-series with given properties. Comparisons between model outcomes and empirical properties will be presented systematically. Full mathematical derivations of the models, as well as methods of statistical inference, model selection and computer codes for parameter estimation on empirical data will be provided.

The course will include a combination of recent and ongoing research in the NETWORKS unit at IMT Lucca, thereby offering directions for possible PhD projects in this area.

Prerequisites: solid mathematical background, scientific curiosity, interest in multidisciplinary, passion for theory.

Hours: 20

Professors/Lecturers: Diego Garlaschelli (IMT Lucca)

Available for: Analysis and Management of Cultural Heritage; Cognitive, Computational and Social Neurosciences

Advanced Methods for Complex Systems II

Abstract: The second part of the course “Advanced Methods for Complex Systems” focuses on advanced practical applications of the concepts introduced in the first part. In particular, emphasis will be put on the successful areas of pattern detection and network reconstruction from partial information. Network pattern detection is the identification of robust empirical patterns (like scale invariance, clustering, assortativity, reciprocity, motifs, etc.) that are widespread across real-world networks and that deviate systematically from some null hypothesis formalised in terms of a suitable random graph model. The models introduced in part I will then be used here for pattern detection purposes. The problem of community detection will also be covered, with an emphasis on the differences between finding communities in network data and in correlation matrices constructed from (e.g. financial or neural) time series databases. The problem of network reconstruction from partial topological information will be addressed concentrating on the reconstruction of financial and interbank networks from node-specific properties, with the purpose of improving stress tests and systemic risk estimates in real markets and offering better tools to policy makers. The statistical physics methods recently found by central banks to be the best-performing reconstruction techniques will be reviewed in detail.

The course will include a combination of recent and ongoing research in the NETWORKS unit at IMT Lucca, thereby offering directions for possible PhD projects in this area.

Prerequisites: solid mathematical background, scientific curiosity, interest in multidisciplinary, successful completion of the course “Advanced Methods for Complex Systems I”. Note: completion of this second part of the course is not required in order to move on to the third part (parts II and III can be understood in parallel independently of each other, after part I is completed), although it would surely provide a useful overview of practical motivations for part III.

Hours: 20

Professors/Lecturers: Diego Garlaschelli (IMT Lucca)

Available for: Analysis and Management of Cultural Heritage; Cognitive, Computational and Social Neurosciences

Advanced Methods for Complex Systems III

Abstract: The third part of the course “Advanced Methods for Complex Systems” focuses heavily on deeper theoretical aspects and their consequences. Particular emphasis will be put on the distinction between maximum-entropy models of complex systems with “soft” and “hard” properties. In statistical physics, the resulting models are known as the “canonical” and “microcanonical” ensembles respectively. Many of the results in statistical physics (e.g. the calculation of certain entropies), discrete mathematics (e.g. the combinatorial enumeration of possible configurations of a system with given properties), and information theory (e.g. the calculation of the maximum compressibility of information sequences) rely of the concept of “ensemble equivalence”, i.e. the asymptotic equivalence of soft and hard ensembles in the large size limit. Surprisingly, various complex systems have been found to violate the property of ensemble equivalence. For these systems, the standard approach is not appropriate and new developments are needed. Several intriguing challenges open up, including the uniform sampling of realisations of large complex systems, the combinatorial enumeration of systems with heterogeneous constraints and the recalculation of traditional information-theoretic bounds on communication. Examples of these open challenges will be provided, along with tentative solutions that are underway.

The course will include a combination of recent and ongoing research in the NETWORKS unit at IMT Lucca, thereby offering directions for possible PhD projects in this area.

Prerequisites: unlimited passion for theory and multidisciplinary, successful completion of the course “Advanced Methods for Complex Systems I”. Note: knowledge of the content of the course “Advanced Methods for Complex Systems II” is not required (parts II and III can be understood in parallel independently of each other, after part I is completed), although it would surely provide a useful overview of practical motivations for this part.

Hours: 20

Professors/Lecturers: Diego Garlaschelli (IMT Lucca)

Available for: Analysis and Management of Cultural Heritage; Cognitive, Computational and Social Neurosciences

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: 44

Professors/Lecturers: Nicola Vanello (Università degli Studi di Pisa); Mauro Costagli (Fondazione IMAGO7 Pisa); Giulio Bernardi (IMT Lucca); Andrea Leo (IMT Lucca); Marcello Massimini (Università degli Studi di Milano)

Compulsory for: Cognitive, Computational and Social Neurosciences

Advanced Seminars (long seminar without exam)

Abstract: TBD

Hours: 30

Professors/Lecturers: Maria Luisa Catoni (IMT Lucca)

Compulsory for: Analysis and Management of Cultural Heritage

Also available for: Cognitive, Computational and Social Neurosciences

Advanced Topics in Network Theory: Algorithms and Applications

Abstract: Centrality metrics and spectral properties of graphs.

Community detection.

Bipartite and multilayer networks.

Applications: World Trade Web

Lecture 1: Centrality metrics

Lecture 2: Spectral properties

Lecture 3: Ranking 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 networks I

Lecture 10: Infrastructural networks II

Hours: 10

Professors/Lecturers: Guido Caldarelli (IMT Lucca)

Available for: Cognitive, Computational and Social Neurosciences

Advanced Topics in Network Theory: Brain Networks

Abstract: We shall provide the theoretical basis of the measurements and analysis of the various kind of network we can define in the brain.

Hours: 10

Professors/Lecturers: Guido Caldarelli (IMT Lucca)

Available for: Analysis and Management of Cultural Heritage; Cognitive, Computational and Social Neurosciences

Advanced Topics in Network Theory: Complex Networks and Python

Abstract: The course must be intended as a laboratory for the theoretical parts explained in the course of Introduction to Complex Networks, It will cover the basic preparation of the pc for the python coding and some example of interest in order to be able to start computational activity in the field of complex networks.

Hours: 10

Professors/Lecturers: Guido Caldarelli (IMT Lucca)

Available for: Cognitive, Computational and Social Neurosciences

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 field
Lecture 4: Epidemics on networks
Lecture 5: Scaling and percolation on networks
Lecture 6: Contagion in financial networks I
Lecture 7: Contagion: financial networks 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)

Available for: Cognitive, Computational and Social Neurosciences

Advanced Topics in Network Theory: Statistical Mechanics of Networks

Abstract: Information theory, Exponential Random Graphs.
Hypothesis testing on networks
Reconstruction of networks.

Lecture 1: Basics of Information Theory
Lecture 2: Complex Networks Randomization
Lecture 3: Exponential Random Graphs
Lecture 4: maximum Likelihood Estimation
Lecture 5: Hypothesis testing on networks
Lecture 6: Early warnings in economic and financial networks
Lecture 7: Gravity Models of Trade
Lecture 8: Reconstruction algorithms I
Lecture 9: Reconstruction algorithms II
Lecture 10: Reconstruction of interbank networks

Hours: 10

Professors/Lecturers: Guido Caldarelli (IMT Lucca)

Available for: Analysis and Management of Cultural Heritage; Cognitive, Computational and Social Neurosciences

Basic Linear Algebra and Statistics for Neuroscience

Abstract: Linear algebra (G. Gnecco):

This part of the course will be based on the book "When life is linear: from computer graphics to bracketology" by Tim Chartier. It will provide a basic introduction to linear algebra to students with no (or minimal) background on it. The emphasis will be on the description of some applications of linear algebra, including some of interest to students in neuroscience, such as basic image processing, principal component analysis, and clustering. More advanced material will be provided upon request to students having already a solid background in linear algebra.

Statistics (V. Tortolini):

This part of the course will provide students with an introduction to probability and statistics and it will be focused on topics that are particularly relevant to neuroscience. The lessons will be designed for students with a minimum knowledge of the subject and based on the book "Learning to use statistical tests in psychology" by J. Green and M. D'Oliveira.

The topics covered will be:

- Introduction to probability: random variables, discrete and continuous distributions
- Introduction to statistics: definition of statistical model, estimate and estimator, point estimation and interval estimation
- Statistical tests: parametric and non parametric tests
- Analysis of Variance: one-way and two-way ANOVA
- Relation between variables: linear model, multiple regression

Hours: 20

Professors/Lecturers: Giorgio Stefano Gnecco (IMT Lucca); Valentina Tortolini (IMT Lucca)

Compulsory for: Cognitive, Computational and Social Neurosciences

Basic Neuro-Linguistics

Abstract: Language springs from distributed, basic as well as higher sensory and cognitive functions. The course will explore the evolutionary and neural bases of language development, from the low-level perceptual-motor stage to the combinatorial, attentive, mnemonic processes driving morphosyntax and eventually, semantics and conceptualization.

Hours: 12

Professors/Lecturers: Alessandra Rampinini (IMT Lucca)

Available for: Analysis and Management of Cultural Heritage; Cognitive, Computational and Social Neurosciences

Basic Principles and Applications of Brain Imaging Methodologies to Neuroscience

Abstract: The course aims at introducing the fundamentals of brain metabolism and brain imaging methodologies. Neuroimaging techniques provided cognitive and social neuroscience with an unprecedented tool to investigate the neural correlates of behavior and mental functions. Here we will review the basic principles, research and clinical applications of positron emission tomography (PET), functional magnetic resonance imaging (fMRI), electroencephalography (EEG) and magnetoencephalography (MEG), non-invasive brain stimulation tools. Solid background in the concepts common to many types of neuroimaging, ranging from study design to data processing and interpretation, will be discussed to address neuroscientific questions. In particular, we will first review the basics of neurophysiology to understand the principles of brain imaging. Then, methodologies of data processing for the main brain imaging tools will be provided to the students with hands-on sessions: students will become familiar with the main pipelines for PET, fMRI and EEG data reconstruction, realignment, spatio-temporal normalization, first and second-level analyses. At the end of the course, students are expected to have general background knowledge of the basic principles, methodologies and applications of the most important brain functional techniques and to be prepared to evaluate the applicability of, and the results provided by, these methodologies for different problems in cognitive and clinical neuroscience.

Hours: 74

Professors/Lecturers: Emiliano Ricciardi (IMT Lucca); Monica Betta (IMT Lucca); Simone Rossi (Università degli Studi di Siena); Luca Cecchetti (IMT Lucca); Luca Turella (Università degli Studi di Trento)

Compulsory for: Cognitive, Computational and Social Neurosciences

Basic Programming for Neuroscience

Abstract: TBD

Hours: 20

Professors/Lecturers: Monica Betta (IMT Lucca)

Available for: Cognitive, Computational and Social Neurosciences

Behavioral and Cognitive Neuroscience of Perception

Abstract: The course will review the physiological and anatomical bases of perception in humans and will consequently detail the neural bases of unimodal, multisensory and supramodal perception. The last part of the course will review recent observation in early and late blind individuals to understand how the (lack of) visual experience affects brain functional and structural development.

Hours: 48

Professors/Lecturers: Emiliano Ricciardi (IMT Lucca); Davide Bottari (IMT Lucca)

Compulsory for: Cognitive, Computational and Social Neurosciences

Also available for: Analysis and Management of Cultural Heritage

Behavioral Economics

Abstract: The course is a self-contained presentation and discussion of the state-of-the-art research in behavioral economics, an area merging economics and psychology for the purpose of modelling and predicting human decision-making and behavior.

The goal of the course is to provide an all-purpose introduction to behavioral economics as well as to offer hooks and suggestions for cutting-edge research projects.

While a general understanding of game theory is welcome, no prerequisite is strictly necessary.

Specific topics covered:

1. What is Behavioral Economics? An economist's take on surprising human behaviors, with a reference to why psychologists and neuroscientists are hardly surprised
2. Rationality with cognitive bounds: Searching for predictable mistakes
3. Beyond homo economicus: Searching for predictable other-regarding preferences
4. A case study in behavioral game theory: Foundations of human prosociality
5. A discussion on methods: Experiments by economists in the lab and in the field, with a reference to how psychologists and neuroscientists would disagree.

Hours: 20

Professors/Lecturers: Ennio Bilancini (IMT Lucca)

Available for: Cognitive, Computational and Social Neurosciences

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: Analysis and Management of Cultural Heritage; Cognitive, Computational and Social Neurosciences

Clinical Psychopathology and Psychiatry

Abstract: TBD

Hours: 10

Professors/Lecturers: Pietro Pietrini (IMT Lucca)

Available for: Analysis and Management of Cultural Heritage; Cognitive, Computational and Social Neurosciences

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: 30

Professors/Lecturers: Mirco Tribastone (IMT Lucca)

Available for: Cognitive, Computational and Social Neurosciences

Contextual Analysis and Individual Objects: Arts, Sciences, Techniques, Beliefs (the course includes research field trips)

Abstract: Contextual Analysis and Individual Objects: Arts, Sciences, Techniques, Beliefs (the course includes research field trips)

Hours: 30

Professors/Lecturers: Linda Bertelli (IMT Lucca)

Compulsory for: Analysis and Management of Cultural Heritage

Also available for: Cognitive, Computational and Social Neurosciences

Critical Thinking (long seminar without exam)

Abstract: Constructing and evaluating arguments is fundamental in all branches of science, as well as in everyday life. The seminar provides the basic skills and tools to recognize correct forms of inference and reasoning, detect the unsound or fallacious ones, and assess the strength of various kinds of argument. The toolbox includes elementary deductive logic, naïve set theory, patterns of inductive and abductive inference, and elements of statistical and probabilistic reasoning. By engaging in real-world exercises of correct and incorrect reasoning, students will familiarize with the analysis of basic

epistemological notions (truth vs. certainty, knowledge vs. belief, theory vs. evidence, etc.) and of common heuristics and biases as studied in cognitive psychology and behavioral economics. No previous knowledge of logic, philosophy, or advanced mathematics is required.

Hours: 10

Professors/Lecturers: Gustavo Cevolani (IMT Lucca)

Available for: Analysis and Management of Cultural Heritage; Cognitive, Computational and Social Neurosciences

Data Science Lab

Abstract: The aim of this class is to provide students with R language fundamentals and basic syntax. 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: 40

Professors/Lecturers: Tbd; Valentina Tortolini (IMT Lucca)

Available for: Cognitive, Computational and Social Neurosciences

Decision-Making in Economics and Management

Abstract: The main goals of the course are:

- (1) to take economic theories and methodologies out into the world, applying them to interesting questions of individual behavior and societal outcomes;
- (2) to develop a basic understanding of human psychology and social dynamics as they apply to marketing contexts;
- (3) to become familiar with the major theory and research methods for analyzing consumer behavior;
- (4) to develop market analytics insight into consumer actions.

Most of time will be devoted to close reading of research papers, including discussion of the relative merits of particular methodologies. Students will participate actively in class discussion, engage with cutting-edge research, evaluate empirical data, and write an analytical paper. The course aims at enabling students to develop and enhance their own skills and interests as applied microeconomists.

Hours: 10

Professors/Lecturers: Massimo Riccaboni (IMT Lucca)

Compulsory for: Analysis and Management of Cultural Heritage

Also available for: Cognitive, Computational and Social Neurosciences

East and West, Present and Past: The Cultural and Political Interplays between the Arabic World and Europe

Abstract: The course will consist of three main sections, historical, political, and aesthetic, respectively.

1) Historical Background: “Philosophy from West to East, to West again”. Analysis of the process through which a “terra franca” of philosophical culture spread in the Abrahamic monotheisms (Christianity, Islam, Judaism) around the Mediterranean Sea in the Middle Ages, and joined intellectuals belonging to each of these three religions in a trans-national scientific community. Basic information on the key-figures and moments of the process: from Aristotle to Dante Alighieri (d. 1321), passing through the Greek-into-Arabic and the Arabic-into-Latin translations of classical texts of philosophy, with special attention to the Islamic, Jewish, and Christian protagonists of the process, and to specific examples of trans-religious interaction. Reflexes of the philosophers’ views in Medieval art and iconography.

2) Political Perspective: “The Past and the Present”. Through the aforementioned process, a well-defined paradigm of intercultural synergy took shape in the Middle Ages for the first time in history: Greek philosophy, shared through translations, provided a common rational basis to distinct cultures, each one of which affirmed its own language, religion, and political status, but was nonetheless able to interact with the others at a high cultural level, notwithstanding religious and political antagonisms, thanks to the universalizing force of the shared philosophical tradition. The peak of Medieval rationalism is reached in Arabic-Islamic philosophy, which pursues the goal of a totally rational – and, by the same token, moderate and tolerant – version of the Muslim religion, in replacement of the more literalist and radical interpretation by theologians. This Medieval pattern holds significant actuality and can be applied in various ways to the contemporary scenario: it regards the role of education in multi-ethnic communities; the emergence of new international and a-confessional issues and concerns; the re-assessment of the “de-radicalizing” role of philosophy in contemporary culture. Discussion of the motives of “clash of civilizations”, “cultural roots of Europe”, and “radicalism vs. tolerance”.

3) Aesthetic Dimension: “Images in Texts, and Texts in Images”. On the one hand, a decorative apparatus of “Western” ascendance is an integral part also of Eastern medieval manuscripts of philosophy: illuminations highlight pivotal parts of the text, illustrations help understanding the content, and decorations depict visually the work in globo; the status of “image” in Eastern medieval philosophical manuscripts has peculiar cognitive aspects of its own, since the text is often copied in geometrical and artistic shapes, raising the issue of whether the text or the image is the copyist’s main aim and the reader’s prime visual object, and of the perceptive relationship between the two. On the other hand, the Arabic script, deprived of any conceptual meaning, detached from religious connotations, and taken simply as an image, appears frequently as a decorative element in Western pieces of art (paintings, sculptures, buildings).

Hours: 60

Professors/Lecturers: Amos Bertolacci (IMT Lucca)

Compulsory for: Analysis and Management of Cultural Heritage

Also available for: Cognitive, Computational and Social Neurosciences

Experimental Economics

Abstract: TBD

Hours: 20

Professors/Lecturers: Tbd

Available for: Cognitive, Computational and Social Neurosciences

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: Analysis and Management of Cultural Heritage; Cognitive, Computational and Social Neurosciences

Forensic Psychology and Psychiatry

Abstract: TBD

Hours: 10

Professors/Lecturers: Pietro Pietrini (IMT Lucca)

Available for: Analysis and Management of Cultural Heritage; Cognitive, Computational and Social Neurosciences

Foundations of Probability and Statistical Inference

Abstract: This course covers 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, copula functions,
- 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.

Hours: 30

Professors/Lecturers: Irene Crimaldi (IMT Lucca)

Available for: Cognitive, Computational and Social Neurosciences

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: Analysis and Management of Cultural Heritage; Cognitive, Computational and Social Neurosciences

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: Ennio Bilancini (IMT Lucca)

Available for: Cognitive, Computational and Social Neurosciences

Introduction to Cognitive and Social Psychology

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: Analysis and Management of Cultural Heritage; Cognitive, Computational and Social Neurosciences

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 1 Graph Theory Introduction
Lecture 2 Properties of Complex Networks
Lecture 3 Communities
Lecture 4 Different Kind of Graphs
Lecture 5 Ranking
Lecture 6 Static Models of Graphs
Lecture 7 Dynamical Models of Graphs
Lecture 8 Fitness Models
Lecture 9 World Trade Web
Lecture 10 Financial Networks

Hours: 10

Professors/Lecturers: Guido Caldarelli (IMT Lucca)

Available for: Analysis and Management of Cultural Heritage; Cognitive, Computational and Social Neurosciences

Introduction to Neuropsychology

Abstract: TBD

Hours: 12

Professors/Lecturers: Francesca Garbarini (Università degli Studi di Torino)

Available for: Cognitive, Computational and Social Neurosciences

Introduction to Psychophysics

Abstract: TBD

Hours: 12

Professors/Lecturers: Davide Bottari (IMT Lucca)

Available for: Cognitive, Computational and Social Neurosciences

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)

Available for: Cognitive, Computational and Social Neurosciences

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: 40

Professors/Lecturers: Andrea Zocchi; Dario Cacciatore (Whirlpool Corporation)

Compulsory for: Analysis and Management of Cultural Heritage

Also available for: Cognitive, Computational and Social Neurosciences

Matrix Algebra

Abstract: This course is aimed to review the basic concepts of linear algebra:

1. Systems of linear equations: solution by Gaussian elimination, $PA=LU$ factorization, Gauss-Jordan method.
2. Vector spaces and subspaces, the four fundamental subspaces, and the fundamental theorem of linear algebra.
3. Determinant and eigenvalues, symmetric matrices, spectral theorem, quadratic forms.
4. Cayley-Hamilton theorem, functions of matrices, and application of linear algebra to dynamical linear systems.

5. Iterative methods for systems of linear equations.
6. Ordinary least squares problem, normal equations, $A=QR$ factorization, condition number, Tikhonov regularization.
7. Singular-value decomposition, Moore-Penrose pseudoinverse.
8. An economic application of linear algebra: the Leontief input-output model.

Hours: 10

Professors/Lecturers: Giorgio Stefano Gnecco (IMT Lucca)

Available for: Cognitive, Computational and Social Neurosciences

Neural Bases of Consciousness and Sleep

Abstract: The course will provide an introduction to fundamental concepts and current experimental approaches related to the study of the functional and anatomical basis of consciousness in humans. In particular, the course deals with the following topics:

- a) Definition of consciousness and identification of its fundamental properties;
- b) The neuroanatomical basis of consciousness;
- c) Altered states of consciousness: sleep, anesthesia, seizures, coma and related conditions;
- d) Main experimental paradigms and methodological approaches to the study of consciousness;
- e) Sleep as a model for the study of consciousness: local aspects of sleep and wakefulness.

Hours: 12

Professors/Lecturers: Giulio Bernardi (IMT Lucca)

Available for: Cognitive, Computational and Social Neurosciences

Neurobiology of Emotion and Behavior

Hours: 12

Professors/Lecturers: Pietro Pietrini (IMT Lucca)

Compulsory for: Cognitive, Computational and Social Neurosciences

Also available for: Analysis and Management of Cultural Heritage

Neuroscience in Bio-Engineering and Robotics

Abstract: TBD

Hours: 18

Professors/Lecturers: Andrea Leo (IMT Lucca); Domenico Prattichizzo (Università degli Studi di Siena); Enzo Pasquale Scilingo (Università di Pisa)

Available for: Cognitive, Computational and Social Neurosciences

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: Cognitive, Computational and Social Neurosciences

Philosophical and Ethical Themes in Neuroscience

Abstract: Since its formal establishment as a self-standing field, neuroethics has been divided into two subdefinitions: the neuroscience of ethics and the ethics of neuroscience. While the neuroscience of ethics aims at explaining the way our brain works in relation to moral judgement, the ethics of neuroscience is a further expansion of bioethics: a discipline that wants to assess the moral dilemmas specifically raised by recent biotechnological advancements. As suggested by the title, this introductory course will focus on neuroethics in this latter sense, underlining the impact that discoveries concerning our brain can, do or will have on our society. Speculating over the ethical and political acceptability of certain innovations in the light of classical philosophical questions (i.e. What is justice? What constitutes a good life?) and other key terms necessary to understand the current debate (i.e. authenticity and personal identity, autonomy, responsibility and competence) will provide the groundworks for any further neuroethical investigation envisaged.

Hours: 10

Professors/Lecturers: Mirko Daniel Garasic

Available for: Analysis and Management of Cultural Heritage; Cognitive, Computational and Social Neurosciences

Philosophy and Neuroscience in Moral Reasoning

Abstract: The analysis of moral reasoning and surrounding topics – how to assess “good” and “bad” actions, how to choose between them, how to justify these choices – is a classical problem of moral philosophy (ethics). More recently, moral psychologists started tackling those problems using a descriptive, empirically based approach. Still more recently, “neuroethicists” began investigating the neural correlates of moral judgment and the implications of neuroscientific results for moral philosophy. The course is an introduction to the essential issues arising at the interface of neuroscience, moral psychology, and moral philosophy. We shall explore problems concerning the biological and neural bases of moral thinking, the role of emotions in moral reasoning, the significance of empirical results for normative theories of morality, and some methodological issues arising within neuroethics. Students are expected to read in advance the papers discussed on each class and to give a brief oral presentation of a topic of their choice.

Hours: 12

Professors/Lecturers: Gustavo Cevolani (IMT Lucca)

Available for: Analysis and Management of Cultural Heritage; Cognitive, Computational and Social Neurosciences

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 seminar will focus on some central patterns of reasoning and argumentation 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. We shall discuss classical examples and case studies from the history and practice of scientific inquiry to illustrate the relevant problems and theoretical positions. Students will freely engage in brainstorming on these topics and are welcome to propose examples, problems, and methods from their own disciplines. No previous knowledge of either logic or philosophy is required.

Hours: 10

Professors/Lecturers: Gustavo Cevolani (IMT Lucca)

Available for: Analysis and Management of Cultural Heritage; Cognitive, Computational and Social Neurosciences

Principles of Brain Anatomy and Physiology

Abstract: The course aims at introducing the fundamentals of brain anatomy and physiology. In the first part of the course we will revise the basics of neuron structure and function, as well as synaptic mechanisms and cytoarchitectonic properties of the cortical mantle, with particular regards to visual, auditory, somatosensory and motor systems. Moving from this fine-grained description of the human brain, we will focus on gross neuroanatomy: through the use of in-vivo state-of-the-art techniques, such as structural MRI and diffusion weighted imaging, we will review gyri and sulci of the cortex, subcortical structures, brainstem nuclei and major white matter fasciculi. The second part of the course will be devoted to the study of functional neuroanatomy, with insights on the relationship between specific brain structures and human cognition, collected using functional, metabolic and receptors mapping, as well as lesion studies. In particular, the the following topics will be covered: central and peripheral nervous systems, occipital parietal frontal temporal and limbic areas, subcortical nuclei and white matter fasciculi, cerebellum, methodologies of structural brain imaging: VBM, cortical thickness and folding, VLSM, Diffusion Weighted Imaging and Tractography (theory and methodologies of data processing, hands-on sessions). The last part of the course will instead cover topics related to peripheral and autonomous nervous system.

Hours: 36

Professors/Lecturers: Luca Cecchetti (IMT Lucca); Michele Emdin (Scuola Superiore Sant'Anna Pisa)

Compulsory for: Cognitive, Computational and Social Neurosciences

Research Seminars

Abstract: TBD

Hours: 30

Professors/Lecturers: Pietro Pietrini (IMT Lucca)

Compulsory for: Cognitive, Computational and Social Neurosciences

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: Tbd

Available for: Analysis and Management of Cultural Heritage; Cognitive, Computational and Social Neurosciences

Seminars in Neuroscience

Abstract: TBD

Hours: 10

Professors/Lecturers: Tbd

Compulsory for: Cognitive, Computational and Social Neurosciences

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).

Hours: 30

Professors/Lecturers: Irene Crimaldi (IMT Lucca)

Available for: Cognitive, Computational and Social Neurosciences

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: Analysis and Management of Cultural Heritage; Cognitive, Computational and Social Neurosciences

Topics in Visual Arts

Abstract: TBD

Hours: 12

Professors/Lecturers: Emanuele Pellegrini (IMT Lucca); Maria Luisa Catoni (IMT Lucca); Linda Bertelli (IMT Lucca)

Available for: Analysis and Management of Cultural Heritage; Cognitive, Computational and Social Neurosciences