Corsi Offerti per l’anno 2022/2023

(last update: April 19, 2023)

Curriculum in Matematica

Si ricorda che, ai sensi del regolamento, "i corsi e gli esami previsti nel piano di studi devono inserirsi in almeno due tematiche diverse"; per tematica si intende settore scientifico disciplinare (N.B. i Settori Scientifico Disciplinari della matematica sono i seguenti: MAT/01 Logica Matematica, MAT/02 Algebra, MAT/03 Geometria, MAT/04 Matematiche complementari, MAT/05 Analisi matematica, MAT/06 Probabilità e statistica matematica, MAT/07 Fisica Matematica, MAT/08 Analisi Numerica, MAT/09 Ricerca Operativa; quindi ad esempio Algebra e Geometria sono due diversi SSD.)

Title: Spectral solution in time of differential equations
Lecturer: Luigi Brugnano (Università di Firenze)
Hours/ECTS: 15-20 / 3-4
Period: end of May / beginning of June
Course presentation: Recently, the numerical solution of a number of differential problems, such as:
1) ordinary differential equations,
2) delay differential equations,
3) fractional differential equations,
has been tackled by using methods which can be regarded as a local expansion of the vector field along a suitable orthonormal basis. This approach allows to derive a number of methods for their solution, possessing peculiar properties (such as energy-conservation for Hamiltonian problems). This approach naturally extends to derive spectral methods in time for solving the above mentioned problems.
This short course is aimed at providing an insight on the above issues (some of them are still open or in progress).
References: see [84,118,119,122,124,126-128,132-134,137,138,142,144,147-149] at http://web.math.unifi.it/users/brugnano/files/elenpub.html
University: Firenze
Webpage: http://web.math.unifi.it/users/brugnano

Title: Spectral methods in applied mathematics
Lecturer: Lorenzo Fusi (Università di Firenze)
Hours/ECTS: 20 / 4
Period: march 2022
Course presentation:
Spectral collocation methods consist in a class of numerical methods used to solve ordinary differential differential equations (ODEs) and partial differential equations (PDEs).
These methods are particularly efficient when one considers simple domains (they can achieve a level of accuracy five times bigger than the alternatives), demanding less computer memory than other methods. In spectral methods solutions are sought by means of high order polynomial expansions (notably, trigonometric polynomials for periodic solutions and orthogonal polynomials for non-periodic solutions). In applied mathematics they are often used to solve boundary and initial value problems occurring in various fields of application (geomechanics, biology, chemistry, physics, fluid dynamics ecc).

We shall present the essentials of spectral collocation methods (Differentiation matrices, Fast Fourier Transform, Clustered Grids, Chebyshev Series, ecc) and see how the can easily be implemented on Matlab to solve some classical problems arising in fluid mechanics, quantum mechanics, linear and nonlinear elasticity.

Bibliography:

[1] Trefethen L.N., Spectral Methods in Matlab, SIAM 2000.

[2] Canuto C., Hussaini M.Y., Quarteroni A., Zang T.A., Spectral methods in fluid dynamics, Springer 1988.

University: Firenze

Webpage: http://web.math.unifi.it/users/fusi/

Title: Spline models for data analysis

Lecturer: Costanza Conti

Hours/ECTS: 10 / 2

Period: November 2022

Course presentation: Spline models have attracted a great deal of attention in recent years and have been widely used in many areas of science and engineering, such as signal and image processing, computer graphics, and, more recently, deep learning and neural networks, or Isogeometric Analysis. In particular, splines are an important tool in the regression model framework to model and predict data trends.

The course aims at providing an introduction to basic spline models (smoothing, regression, and penalized splines) based on polynomial splines, exponential-polynomial splines, L-splines. It also aims at giving a general overview of more advanced models, including nonparametric and nonlinear regression splines. Two models will be described in detail: smoothing splines and penalized least squares splines. Methods for parameter selection of PSplines and HPSplines will also be discussed.

University: Firenze

Webpage: https://www.unifi.it/p-doc2-2013-200006-C-3f2a3d3034292c-0.html

----

Title: Consensus-Based Optimization

Lecturer: Massimo Fornasier (Technical University of Munich)

Hours/ECTS: TBD

Period: TBD

Course presentation: High-dimensional Global optimization of complicated nonconvex/nonsmooth functions can be a formidable mathematical and numerical problem with a vast number of possible applications, not last in machine learning. Consensus-based optimization (CBO) is a multi-particle metaheuristic derivative-free optimization method that can globally minimize nonconvex nonsmooth functions and is amenable to theoretical analysis. In fact, optimizing agents (particles) move on the optimization domain driven by a drift towards an instantaneous consensus point, which is computed as a convex combination of particle locations, weighted by the cost function according to Laplace's principle, and it represents an approximation to a global minimizer. The dynamics is further perturbed by a random vector field to favor exploration, whose variance is a function of the distance of the particles to the consensus point. In particular, as soon as the consensus is reached the

stochastic component vanishes. As the dynamics of the algorithm can be described as an Euler-Maruyama approximation scheme of a system of stochastic differential equations (SDE), the first part of the course is about a concise primer on stochastic calculus and stochastic differential equations. We also need to introduce the concept of mean-field limit, to show how the law of the the system of SDE converges in a suitable (weak) sense for the large particle limit to the solution of a partial differential equation (PDE) of Fokker-Planck-type. The combination of the analysis of the large time behavior of the solution of the PDE with the mean-field limit will then be the key strategy to prove the global convergence of the algorithm. The result unveils the internal mechanisms of CBO that are responsible for the success of the method. In particular, the convergence proof will show that essentially CBO performs a convexification of a very large class of optimization problems as the number of optimizing agents goes to infinity. We further present formulations of CBO over compact hypersurfaces and the proof of convergence to global minimizers for nonconvex nonsmooth optimizations on the hypersphere. We further mention further variations of CBO to include anisotropic noise and impulsive noise exploration, to approximate other methods such as particle swarm optimization, and numerical tricks and implementations. We conclude the course with several numerical experiments, which show that CBO scales well with the dimension and is extremely versatile. To quantify the performances of such a novel approach, we show that CBO is able to perform essentially as good as ad hoc state of the art methods using higher order information in challenging problems in signal processing and machine learning, namely the phase retrieval problem, the robust subspace detection, and training of neural networks.
References:

- M. Fornasier, H. Huang, L. Pareschi, P. S unnen, Consensus based optimization on hypersurfaces: Well-posedness and mean-eld limit, M3AS, 2021
- M. Fornasier, H. Huang, L. Pareschi, P. S unnen, Consensus based optimization on the sphere: Convergence to global mininizers and machine learning, JMLR, 2021
- M. Fornasier, H. Huang, L. Pareschi, P. S unnen, Anisotropic di usion in consensus-based optimization on the sphere, SIOPT, 2022
- M. Fornasier, T. Klock, K. Riedl, Consensus-based optimization methods converge globally, arXiv:2103.15130, submitted to FoCM, 2021
- M. Fornasier, T. Klock, K. Riedl, Convergence of anisotropic consensus-based optimization in mean-field law, International Conference on the Applications of Evolutionary Computation, 2022

University: Firenze/online
Webpage: https://www.professoren.tum.de/en/fornasier-massimo

Title: Research themes and methods in the history of mathematics
Lecturer: Riccardo Bellè (Università di Pisa), Alberto Cogliati (Università di Pisa), Veronica Gavagna (Università di Firenze)
Hours/ECTS: 25 / 5
Period: March-May 2023
Course presentation: The course aims to describe some aspects of research in history of mathematics, showing how the study of different themes and historical periods requires different approaches and tools of inquiry.
The first part of the course will focus on Greek mathematics, particularly on the geometry of Euclid and Archimedes. We will talk about the textual tradition and the translations of the

Elements and the Archimedean corpus. We will then see the relevance of these issues in Renaissance Humanism in the context of the restoration of the Greek mathematical Classics. We will see how the techniques of digital philology can be a valuable support for the reconstruction of the textual tradition. To this end the participants will use a software to compare and analyze some Archimedean passages taken from three different witnesses: the editio princeps of the Archimedean corpus (Basel, 1544) and the autograph fifteenth-century manuscripts Nouv. Acq. Lat. 1538 (Paris, Bibl. Nat. de France) and Cent. V 15 (Nürnberg, Stadtbibliothek) by Iacopo of St. Cassianus and Johannes Müller of Königsberg (Regiomontanus), respectively.
In the second part of the course we will describe elementary methods of historical research that can be applied in the critical examination of printed mathematical texts of the past. We will provide examples of critical reading taken from the history of the parallel theory and the history of non- Euclidean geometries. Texts to be examined include excerpta from C. Clavio, Euclidis Elementorum Libri XV, Roma, 1589; G. Saccheri, Euclides ab omni naevo vindicatus, Milano,1733; J. Bolyai, Appendix. Scientiam Spatii absolute vera exhibens: a veritate aut falsitate Axiomatis XI Euclidei (a priori haud unquam decidenda) indipedentem, 1832 and N. Lobačevskij, Geometrische Untersuchungen zur Theorie der Parallellinien, Berlino, 1840.
University: Firenze
Webpage: https://unimap.unipi.it/cercapersone/dettaglio.php?ri=4726, https://www.dm.unipi.it/people/cogliati-alberto/, https://www.unifi.it/p-doc2-2020-0-A-2c2a3a2f3330-1.html

----

Title: Geometry and topology of Kähler manifolds
Lecturer: Daniele Angella (Università di Firenze), Francesco Pediconi (Università di Firenze), Giovanni Placini (Università di Firenze)
Hours/ECTS: 30 / 6
Period: February 7, 2023
Course presentation:
Complex manifolds are manifolds with biholomorphic changes of coordinates. Their topology is still mysterious and an active research field. A first step in understanding this topic is to restrict to the subclass of projective manifolds and their analytic analogues, the so-called Kähler manifolds.
In this course, we present some results concerning the geometry and topology of Kähler manifolds. We first overview the theory of elliptic differential operators, with applications to the cohomology of Riemannian manifolds. We then introduce complex and Kähler geometry, and we study the main results on the cohomology of Kähler and projective manifolds. In the last part of the course, we discuss the following question: which groups are fundamental groups of Kähler manifolds?
Prerequisites: Topology and Differential Geometry.
Tentative plan of the course:
01. Introduction to Riemannian manifolds and elliptic operators on vector bundles.
02. Sobolev spaces on Riemannian vector bundles.
03. The splitting theorem and elliptic regularity.
04. De Rham cohomology and harmonic forms.
05. Hodge theory of Riemannian manifolds.
06. Introduction to Complex Geometry.

07. Geometry and Topology of Complex Manifolds.
08. Hermitian and Kähler manifolds.
09. Cohomology of Kähler manifolds.
10. Hodge theory of projective manifolds.
11. K\"ahler groups: introduction and overview.
12. Applications of the Hard Lefschetz Theorem.
13. The Albanese map and its relation with the cuplength.
14. Castelnuovo-de Franchis and Sia-Beauville theorems.
15. Positive results for finite and infinite groups.
University: Firenze
Webpage: https://sites.google.com/site/danieleangella/, https://sites.google.com/view/francescopediconi/

Title: Fluid Mechanics and Human Circulation
Lecturer: Angiolo Farina (Università di Firenze)
Hours/ECTS: 20 / 4
Period: second semester
Course presentation:
In the proposed course we focus our attention on one of the most intriguing branches of medicine: hematology. Many experimental studies over the years have shown that blood flow exhibits extremely complex characteristics. In this framework mathematics can play an important role, setting up reliable and, at the same time, “simple” models. Indeed, the more difficult are the phenomena to be studied, the more necessary is to simplify equations, and simplifications always need to be justified and kept within a tolerance degree guaranteeing that the model is still meaningful, at least for some specific target. Blood-related topics are so numerous and each subject has been so widely studied that it is unthinkable to treat all of them in a short course. We just deal with some aspects, showing old and new approaches. Indeed, the main objective is to focus on some blood fluid dynamics problems and to illustrate the relative mathematical models, trying to emphasize both the physical aspects and the mathematical techniques. In summary, we analyze some blood flow in specific body vessels. However, as preliminary discussion, we recall some issues concerning the constitutive models that can be used to describe the peculiar blood rheology.
Course plan:
1. The Human Circulatory System
2. Hemorheology and Hemodynamics
   Blood Rheology
   Constitutive Models for Blood
   Microcirculation, vasomotion, Fåhræus–Lindqvist effect
3. Blood Filtration in Kidneys
   General Structure of Kidneys
   Modelling of the filtration process
   The Steady Flow and the Glomerular Filtration Rate
4. Extracorporeal Blood Ultrafiltration
   The hollow fibers dialyzers
   Osmotic pressure
   Modeling the devices

Bibliography:

- Fasano A., Sequeira A.: Hemomath. The Mathematics of Blood. Springer (2017).

University: Firenze
Webpage: https://www.unifi.it/p-doc2-2015-0-A-2c303931382e-0.html

----

Title: Mathematics, Deep Learning and Deep Reinforcement Learning
Lecturer: Maurizio Parton (Università di Chieti-Pescara)
Hours/ECTS: 30 / 6
Period: September/October 2023
Course presentation: The last few years have seen impressive accomplishments of artificial intelligence. Without a doubt, Deep Learning DL and Deep Reinforcement Learning DRL are the techniques that contributed most to these successes. Despite the extremely diverse areas involved (image recognition, games, biology, natural language processing, to name a few), we are still a long way from truly understanding the mathematics behind DL and DRL. Along with its theoretical interest, this would further increase their performance and fields of application.
This course is addressed to mathematicians who aim to understand the relationship between DL/DRL and mathematics, in both directions. How can mathematicians contribute to the mathematical foundations of DL/DRL? How can DL/DRL be used by mathematicians in their everyday research field?
After introducing DRL and DL in the first part of the course, we will provide (very partial) answers to the above questions by introducing some of the recent topics that in my opinion enlight this beautiful link between DL/DRL and mathematics, see bibliography.
I will do my best to make this course accessible to the average mathematician. In particular, 2/3 of the course will be devoted to fundamentals of DRL and DL, so that no prior knowledge of DL or DRL is required. A basic knowledge in probability, algebraic geometry, differential geometry and/or Python could be helpful, but is not essential.
Bibliography.

-) Constructions in combinatorics via neural networks, https://arxiv.org/abs/2104.14516.
-) Geometric deep learning, https://arxiv.org/abs/1611.08097.
-) The Calabi-Yau Landscape, https://arxiv.org/abs/1812.02893.
-) Principles of Riemannian Geometry in Neural Networks,
https://papers.nips.cc/paper/2017/hash/0ebcc77dc72360d0eb8e9504c78d38bd-Abstract.html.
-) Advancing mathematics by guiding human intuition with AI,
https://www.nature.com/articles/s41586-021-04086-x.

University: Firenze
Webpage: https://www.unich.it/ugov/person/1741

Title: Groups, graphs and democracy - An algebraic approach to social choice theory
Lecturer: Daniela Bubboloni (Università di Firenze)
Hours/ECTS: 15 / 3
Period: TBD
Course presentation:

– Note: Professor Daniela Bubboloni is also available to offer courses in graph theory on topics to be discussed with the students. –

Finite groups and social choices: Preference relations and their properties. Orders and linear orders. Preference profiles and symmetric groups. Social choice correspondences and social preference correspondences. The main classic examples. Properties of social choice/preferences correspondences: resoluteness, majority, qualified majority, Condorcet principle, unanimity, anonymity, neutrality. Anonymity and neutrality interpreted by the actions of the direct product of symmetric groups on the set of preference profiles. Moulin's theorem. Existence of social choice correspondences obeying the qualified majority principle. Existence of resolute, unanimous, anonymous and neutral social choice correspondences. The concept of symmetry in social choice theory through group theory. Regular subgroups and their applications. Tie breaking methods. Citizen sovereignty, non-dictatorship, monotonicity and the Muller- Satterthwaite Theorem. Voting methods. impossibility results for voting methods. Committee selection rules.

Finite graphs and social choices: Majority graphs. Ranking methods: Borda method, Schulze network method, Kemeny method.

University: Firenze

Webpage: https://www.unifi.it/p-doc2-2015-0-A-2b333a2a3a2f-1.html

----

Title: Topological methods for differential equations [Metodi topologici nello studio delle equazioni differenziali]

Lecturers: Irene Benedetti and Paola Rubbioni (Università degli Studi di Perugia)

Hours/ECTS: 30/6

Period: March 2, 2023

Course presentation: The course is devoted to the study of Semilinear Differential Equations in abstract spaces by means of topological methods. More precisely, the ordinary differential equations considered are given by a linear part generating a semigroup of linear operators and a nonlinearity with certain regularity properties.

Several techniques to prove existence results for various types of problems will be presented, relying on fixed point theory in connection with measures of noncompactness or other compactness assumptions.

Applications to the study of models driven by partial differential equations will be shown.

A possible plan for the course is the following:

- Fixed point theory in topological vector spaces
- First elements of the semigroup theory
- Existence theorems for semilinear differential equations and inclusions with different boundary conditions and perturbations: nonlocal or periodic initial conditions, delay, controls, impulses
- Applications to reaction-diffusion processes and population dynamics models

University: Perugia

Webpage: https://www.unipg.it/personale/irene.benedetti, https://www.unipg.it/personale/paola.rubbioni

----

Title: Algebraic curves and applications to cryptography and coding theory

Lecturer: Daniele Bartoli (Università di Perugia)
Hours/ECTS: 30 hours / 6 ECTS
Period: TBC March-May 2023
Course presentation: An introduction to algebraic curves over finite fields and related function fields is provided in the first part. Applications to relevant classes of polynomials over finite fields will be given in the second part.
University: Perugia or Firenze
Webpage: https://www.unipg.it/personale/daniele.bartoli

Title: Algebraic structures in geometry
Lecturer: Zbyněk Šír (Università di Praga)
Hours/ECTS: 10-15 / 2-3
Period: April-May, 2023
Course presentation: We will study various ways to represent classes (groups) of geometric transformations using algebraic structures. In particular complex numbers, finite fields, quaternions, dual quaternions, and Clifford algebras will be used. After introducing the necessary formalism we will in particular focus on the construction problems for special curves, surfaces and motions. Some open problems will also be presented.
University: Firenze
Webpage: https://www2.karlin.mff.cuni.cz/~sir/

Title: Optimal Control [Teoria geometrica del controllo e introduzione alla geometria subriemanniana]
Lecturer: Laura Poggiolini (Università di Firenze)
Hours/ECTS: 15/3
Period: May or June 2022
Course presentation: Vector fields, ODEs on manifolds, Lie brackets. Rashevski-Chow Theorem, Frobenius Theorem, Optimal Control: existence of an optimiser. Pontryagin Maximum Principle. Second order sufficient conditions.
University: Firenze
Webpage: https://www.unifi.it/p-doc2-0-0-A-3f2a3d31362b2c.html

----

Title: Galois theory and applications
Lecturer: Marco Timpanella (Università di Perugia)
Hours/ECTS: 20 hours / 4 ECTS
Period: December 2022/January 2023
Course presentation: Galois theory and function field theory are two of the most established topics in mathematics, with historical roots that led to the development of many central concepts in modern mathematics. In recent years, these topics have found surprising applications in other branches of mathematics such as Finite Geometry, Coding Theory, and Cryptography.

The main objective of this course is to provide an in-depth knowledge of Galois theory, and to show how these techniques can be applied to the study of other relevant mathematical objects.
The course is divided into two parts. The first one presents the foundations of field extensions and the interplay between group theory and field theory, formulated via Galois theory.
In the second part, we will focus on Galois extensions of function fields, and their applications to Finite Geometry and Coding Theory.
References:
- J. W. P. Hirschfeld, G. Korchmáros, F. Torres, Algebraic Curves over a Finite Field, Princeton University Press (2008).
- D. A. Cox, Galois Theory, John Wiley & Sons Inc (2012).
- M. D. Fried, M. Jarden, Field Arithmetic, Springer (2008).
- H. Stichtenoth, Algebraic Function Fields and Codes, Springer (2009).

More detailed references will be provided during the course.
University: Perugia

Title: Quantum groups and knot invariants
Lecturer: Carlo Collari (Università di Pisa)
Hours/ECTS: 20 h / 4 CFU
Period: January-February 2023
Course presentation:
In mathematics and theoretical physics, the term "quantum group" denotes (different kinds of) noncommutative algebras with additional structure. These objects sit in the intersection between representation theory, low-dimensional topology, and quantum physics. This course is an introduction to quantum groups and monoidal categories, with an eye towards their connection with low-dimensional topology. In particular, we will be interested in the description of Drinfeld–Jimbo-type quantum groups (i.e. special kinds of Hopf algebras) and their application to the definition of knot invariants.
The final part of the course concerns the connection of quantum invariants with other subjects: low-dimensional topology, representation theory, physics, and statistical mechanics. Some topics among the ones marked below will be covered depending on the students' interests. No prior knowledge about representation theory or knot theory is required as we shall cover the basic facts needed.
Topics/plan of the course:
(QG1) Yang-Baxter equations and braid groups;
(QG2) Hopf Algebras;
(QG3) Monoidal, braided and ribbon categories and graphical calculus;
(QG4) Drinfel'd doubles;
(QG5) A brief review of Lie algebras: sln and its representations;
(QG6) Deformations of enveloping algebras: the quantum group U_q(sl_n);
(QG7) Knots, links, and the Jones polynomial.
(QGx) Invariants of 3-manifolds.*
(QGx) Representations of U_q(sl_n).*
(QGx) Kontsevich integral and Vassiliev invariants.*
(QGx) Quantum invariants and statistical mechanics.*

(QGx) Quantum groups at q = 0 and crystal bases.*
(QGx) Topological Quantum Field Theories.*
(QGx) Categorification of quantum invariants.*
* Depending on the students' interests.
Prerequisites: linear algebra, basic group theory (basic definitions: groups, subgroups, quotients *etc.*), basic commutative algebra (ring, modules, tensor product *etc.*).
University: Firenze
Webpage: https://sites.google.com/view/carlocollari/home

Title: Random graphs and statistical mechanics
Lecturer: Luisa Andreis (Politecnico di Milano), Gianmarco Bet (Università di Firenze)
Hours/ECTS: 20 / 4
Period: December 2022-January 2023
Course presentation:
The advent of the web and the internet, as well as the widespread availability of data on equally complex systems, have sparked an enormous interest in the rigorous study of complex networks. From a mathematical point of view, a network (or, more commonly, a graph) is simply a set of elements (nodes, or vertices) and connections (edges) between them. Typical examples include communication, manufacturing, and protein networks. These systems are so complex that a precise description in terms of a mathematical model is out of reach. One popular way of overcoming this modelling challenge is to consider *random* graphs instead. Indeed, simple probabilistic generative mechanisms give rise to very complicated macroscopic structures, whose characteristics often match real-world data.
Random graph theory is rich with deep theoretical issues (e.g., the theory of phase transitions), as well as modelling successes (e.g., the explanation of power-law tails in terms of the preferential attachment mechanism). The course aims at introducing the audience to the mathematical study of random graphs, and to give a taste of the most recent advancements. The course will cover the two basic static models: the Erd˝os–R´enyi (ER) random graph and the Configuration Model (CM), as well as the main dynamical model: the Preferential Attachment Model. We will give results on the degree sequence, connectivity threshold and connectivity structure of these models. These results are formulated in terms of convergence in probability and of large deviation statements, as the graph size increases. If time allows, we will discuss the connection between random graph theory and statistical mechanics by introducing the Exponential Random Graph, which generalises both the ER random graph and the CM. In the latter part of the course, we will introduce the idea of local weak convergence of graphs, which is a popular way to talk about convergence of sparse graphs.
Depending on the background and interests of the audience, more (or less) emphasis will be placed on theoretical or modelling aspects. Upon request, we will also spend some time reviewing the basic probabilistic tools needed for developing the theory (e.g., coupling, branching processes, martingales, large deviations).
University: Firenze
Webpage: https://people.dimai.unifi.it/bet/, https://sites.google.com/view/luisaandreis/home

----

Title: Global Lorentzian geometry

Lecturer: Ettore Minguzzi (Università di Firenze)
Hours/ECTS: 30 / 6
Period: March-May 2023
Course presentation:
After an introduction to the mathematics of Lorentzian manifolds we shall investigate the consequences of Einstein's general theory of relativity with a focus on the global pathologies of spacetime: black holes, Cauchy horizons, regions of chronology violation, geodesic singularities. We shall prove the main singularity theorems by Hawking and Penrose, and study other global aspects such as the existence of time functions. Hints at generalizations might be present in the course (Finslerian aspects/anisotropy or issues of low regularity).
References:
E.M. Lorentzian causality theory, Living Reviews in Relativity 22, 3 (2019)
Hawking and Ellis, The large scale structure of spacetime CUP 1973
University: Firenze
Webpage: http://www.dma.unifi.it/~minguzzi/

===

Curriculum in Informatica

Elenco Corsi Dottorato Curriculum in Informatica
AA 2022-2023

Title: Affective Computing & Emotion Recognition
Lecturer:
Hours/ECTS:
Period:
Course presentation: Introduction to AI approach to Emotion Recognition (ER) and Affective Computing. Neurophysiological aspects, emotional models (Plutchik), applications. Image based ER, CNN and knowledge transfer techniques. Sound baser ER, spectrogramization, ER in text, PoS, word-to-vec, semantic similarity. Sensors-based and PoB based ER. Insights on emotional intelligence, Mirror Neurons, Social Emotions, Errors, biases and overconfidence.
University: Firenze/Perugia
Webpage:

Title: Introduction to Quantum Computing
Lecturer: Marco Baioletti
Hours/ECTS: 18 ore frontali + 12 di attività individuale (6cfu complessivi)
Period: gennaio-febbraio 2023
Course presentation: Programma di massima: Concetti di base del QC (qubit, gate, circuiti, ecc.). Cenni sulle architetture reali esistenti. Problematiche dei computer quantistici attuali (compilazione dei circuiti, mitigazione degli errori). I piu' famosi algoritmi quantistici (Shor e Grover). L'algoritmo QAOA. Algoritmi per il Quantum Machine Learning. Altri algoritmi quantistici importanti. Modalita' di utilizzo di simulatori e computer quantistici reali. QC e complessita' computazionale. Introduzione alla crittografia quantistica. Introduzione al Quantum Error Correction. I quantum annealer e il loro utilizzo.
University: Perugia
Webpage:

Title:
Lecturer:
Hours/ECTS:
Period:
Course presentation:
University: Firenze/Perugia
Webpage:

Title:
Lecturer:
Hours/ECTS:
Period:
Course presentation:
University: Firenze/Perugia
Webpage:

Title:
Lecturer:
Hours/ECTS:
Period:
Course presentation:
University: Firenze/Perugia
Webpage:

==

Curriculum in Statistica

Title: Basi di informatica per il data scientist (Fundamentals of computer science for the data scientist)
Lecturer:
Hours/ECTS:
Period:
Course presentation: Programmazione in Python: costrutti fondamentali, moduli Python, funzioni, ricorsione, stringhe, liste e dizionari, analisi degli algoritmi, ricerca e sorting. Tecniche algoritmiche: greedy, divide et impera, programmazione dinamica. Grafi e algoritmi su grafi. Algebra relazionale e normalizzazione. Preprocessing di dati di tipo relazionale per applicazioni data mining utilizzando il linguaggio SQL. Introduzione alla Crittografia a chiave condivisa (cifrari di Feistel) e a chiave pubblica (RSA). Firma digitale. Privacy dei dati: k-anonymity e differential privacy.
(Programming in Python: fundamental instructions, python modules, functions, recursion, strings, lists, dictionaries, analysis of algorithms, search, and sorting. Algorithmic techniques: greedy, divide et impera, dynamic programming. Graphs and algorithms on graphs. Relational algebra and normalization.Preprocessing of relational data for data mining applications using theSQL language. Introduction to Shared Key Encryption (Feistel ciphers) and Public Key Encryption (RSA). Digital signature. Data privacy: k-anonymity and differential privacy.)
University: Firenze/Perugia
Webpage:

Title: Elements of statistical inference
Lecturer: Alessandra Mattei, Agnese Panzera, Anna Gottard
Hours/ECTS: 10/2
Period: Nov 22/Jan 23
Course presentation: Mandatory course for the curriculum in Statistics. The course will be held as a flipped class.
University: Firenze

Title: SIMULATION METHODS IN ECONOMETRICS AND STATISTICS
Lecturer: Giorgio Calzolari - Professore a contratto
Hours/ECTS: 10 hours
Period: January 2023
Course presentation:
Monte Carlo simulation methods will be used to "verify" some properties of the traditional estimation methods:
unbiasedness, consistency, asymptotic normality, efficiency, asymptotic efficiency, computational performance.
Students will be requested to make experiments on estimation methods like least squares, instrumental variables,

maximum likelihood. applied to linear regression models, autoregressions, nonlinear regressions, logit/probit models.
Students are allowed to use a programming language of their choice. Suitable programming languages can be
Fortran (the best!), C, C++, Matlab, Python, R (sigh!).
University: Firenze

-- ---

Title: Social demography: models and applications
Lecturer: B. Arpino, R. Guetto, E. Pirani, V. Tocchioni, D. Vignoli
Hours/ECTS: 15 ore
Period: January 2023
Course presentation: The seminars will give an overview on current topics in the field of population studies in contemporary societies. We will propose a critical and in-depth discussion on major social and demographic issues that contemporary societies are facing and on future challenges, also offering new and fresh insights on methodological approaches useful in these domains.
List of proposed seminars:
- We Found Causality in a Hopeless Place. Challenges of Causality in Demographic Observational Studies (BA)
- The growth of mixed unions in Italy: a marker of immigrant integration and societal openness? (RG)
- Social determinants of health (EP)
- Pathways into childlessness. A holistic approach (VT)
- Fertility in the Era of Uncertainty (DV)

University: Firenze

Title: Spatial Data Analysis: advances and applications in economic field
Lecturer: Francesca Adele Giambona
Hours/ECTS: 10/2
Period: January 2023
Course presentation: In economic field the existence of spatial relationships between regions, firms, individuals have been gradually taken into account in the specification of statistical models by using techniques and methods to analyse spatial data considering interaction effects and spatial heterogeneity. In the light of this, the course explores the application of spatial data analysis to analyse economic phenomenon by introducing, also, some advances related for example to spatial quantile and longitudinal spatial models. After a (brief) theoretical introduction to exploratory spatial data analysis (ESDA) and spatial regression models some applications will be proposed to understand the usefulness of spatial analysis in analysing economic aggregates.
University: Firenze

Title: Random effects models for multilevel and longitudinal data

Lecturer: Leonardo Grilli, Carla Rampichini
Hours/ECTS: 10 hours
Period: January - February 2023
Course presentation: The course introduces the theory and practice of random effects (mixed effects) models for the analysis of multilevel data in both cross-sectional and longitudinal settings. Emphasis is placed on model specification and interpretation. The course covers random effects models for continuous responses and for categorical responses.
University: Firenze

--

Title: Latent Variable Models for cross-section and longitudinal data
Lecturer: Silvia Pandolfi
Hours/ECTS: 10 ore
Period: February 2023
Course presentation: The aim of the course is to introduce the fundamental concepts and state-of-art about latent variable models. Specific models, including both discrete and continuous latent variables will be introduced, such as finite mixture, latent class, latent regression, item response theory, and hidden Markov models. Algorithms for maximum likelihood estimation of these models are reviewed, focusing in particular on the Expectation-Maximization algorithm. Model selection, clustering, and computation of standard errors will be discussed. All approaches will be illustrated by means of real data applications implemented through the software R.
University: Perugia

--

Title: Use of auxiliary information for descriptive inference on finite populations
Lecturer: Prof. Giorgio E. Montanari
Hours/ECTS: 10 Hours / 2 ECTS
Period: February-March 2023
Course presentation: this course offers an overview of the use of auxiliary information for estimating finite population parameters, such as totals, means, proportions, and functions of them. After a recall of classical estimators, modern techniques are presented, based on generalized regression estimation, calibration estimation, and non-parametric tools. Furthermore, the use of auxiliary information for the treatment of non-response is also presented, concentrating on one-step and two-step approaches.
University: Perugia

--

Title: Experimental design and statistical models for engineering and quantitative marketing: theory and case studies
Lecturer: Rossella Berni (15 ore); Nedka D. Nikiforova (5 ore)
Hours/ECTS: 20
Period: March-April 2023
Course presentation:

- Fundamental principles of experimental design
- The experimental design in the technological field: planning and modelling
- Split-plot design and modelling
- Computer experiments
- Optimal designs
- Choice experiments and modelling

MAIN REFERENCES:

Cox D.R, Reid (2000), The theory of the design of experiments, Chapman & Hall.
Khuri, A.I. and Cornell, J.A., 1996, Response Surfaces: design and analysis. 2nd Ed. Marcel Dekker, New York.
Searle, S.R., Casella, G., McCulloch, C.E., 1992, Variance components, New Jersey: John Wiley & Sons.
Atkinson, A.C. & Donev, A.N., 1992, Optimum Experimental Designs. Oxford Statistical Scienc
Train K. Discrete Choice Simulation, Cambridge University Press, 2002

NOTE: Oltre ai testi di base, durante il corso le tematiche verranno approfondite tramite articoli scientifici che saranno proposti ai Dottorandi e sui quali si svilupperà una discussione tipo “reading group”, come per il corso precedente, sarà fatto a distanza in live streaming (ovviamente se non sarà possibile svolgerlo in presenza).

University: Firenze

--

Title: Analysis of standardized tests through Item Response Theory
Lecturer: Prof. Silvia Bacci
Hours/ECTS: 10 hours
Period: May 2023
Course presentation: The course introduces the fundamentals of Item Response Theory (IRT) with focus on: motivation for a model-based theory, models for binary items (Rasch model, 2PL model, 3PL model), models for polytomous items (Graded Response Model, Partial Credit Model, Rating Scale Model), Rasch paradigm and specific objectivity, estimation approaches, statistical tools for model and item selection, differential item functioning, test equating. Lessons are organized with theoretical topics and examples with software R.
University: Firenze

--

Title: Fundamentals of Computer Science for the Data Scientist
Lecturer: M. Boreale, A. Marino, D. Merlini, M. C. Verri
Hours/ECTS: 40/8
Period: Spring 2023
Course presentation: The course introduces the fundamentals of computer science for the data scientist. Programming in Python: fundamental structures, python modules,functions, recursion, strings, lists, dictionaries, analysis of algorithms,search, and sorting. Algorithmic techniques: greedy, divide et impera, dynamic programming. Graphs and algorithms on graphs. Relational algebra and normalization. Preprocessing of relational data for data mining applications using the SQL language. Introduction to Shared Key Encryption (Feistel

ciphers) and Public Key Encryption (RSA). Digital signature. Data privacy: k-anonymity and differential privacy.
University: Firenze

Title: Gaussian Mixture Models for Model-Based Clustering, Classification and Density Estimation
Lecturer: Luca Scrucca
Hours/ECTS: 10 Hours / 2 ECTS
Period: TBA
Course presentation: The course introduces Gaussian mixture models, a widely-used family of models that have proved to be an effective and computationally convenient way to perform model-based clustering, classification, and density estimation.
Topics presented during this course are maximum likelihood estimation via the EM algorithm, resampling-based inference, model selection, data simulation, Bayesian regularization, presence of noise and outliers, dimension reduction methods, variable selection for model-based clustering.
All the methods are illustrated using the mclust package for the software R.
University: Perugia

Title: Bayesian Causal Inference
Lecturer: Fan Li (Department of Statistical Science, Duke University, Durham, NC, USA)
Hours/ECTS: 20 ore
Period: June, 2023
Course presentation: The aim of this course is to introduce the fundamental concepts and state-of-art methods for causal inference under the potential outcome framework. The lectures will be organized by the treatment assignment mechanisms. Topics will cover randomized experiments, observational studies with ignorable assignment mechanisms, natural experiments, sequential ignorable longitudinal treatments.
Recent advances related to machine learning and more complex situations such as spatial-temporal treatments and interference will also be discussed. All methods will be illustrated via real case studies in health studies, economics and biology. Though the causal framework and most of the methods are independent of the inferential paradigm, an emphasis will be put on the Bayesian paradigm for inference.
University: Firenze (http://www.mi.imati.cnr.it/conferences/abs23/index.html)

Title: Kernel smoothing
Lecturer: Agnese Panzera
Hours/ECTS: 10 /2
Period: June 2023
Course presentation: Kernel smoothing refers to a general class of techniques for non-parametric estimation of functions. The course offers an overview of the applications of

kernel smoothing ideas to density estimation and regression problems, along with some related issues.
University: Firenze

Title: Bayesian methods for high-dimensional data
Lecturer: Francesco Stingo
Hours/ECTS: 10 /2
Period: May or June 2023
Course presentation: Bayesian approaches for model selection in the context of high-dimensional linear regression, GLM, semi-parametric regression, and graphical models, with applications in bio-medicine, with a particular focus on genomics.
University: Firenze

Title: Approximate Bayesian Computation (ABC)
Lecturer: Fabio Corradi; Cecilia Viscardi
Hours/ECTS: 15 /3
Period: June - July 2023
Course presentation: The course introduces Approximate Bayesian Computation (ABC) - a class of likelihood-free methods for Bayesian inference.
Topics presented during this course: ABC as an explanation of how Bayes rule works; Generative models; ABC with no approximation; Sources of approximation in ABC; Rejection ABC and its convergence to exact Bayesian computation; Limits in the use of Rejection ABC by examples; Examples from network analysis and Population genetics; Trade-off between level of approximation and computational efficiency; Importance Sampling ABC; Markov Chain Monte Carlo ABC. Sequential methods: Population MC and Sequential MC.
At the end of the course, we provide an introduction to some more advanced topics, possibly related to students' research interests, to be further developed in a presentation given by the students during the last lecture.
University: Firenze

Title: Statistical analysis of Spatial Data
Lecturer: Chiara Bocci (Unifi)
Hours/ECTS: 12/2
Period: Luglio 2023
Course presentation:
The aim of the course is to introduce students to statistical techniques for the analysis of spatial data, that is data that exhibit a spatial dependence. After the presentation of stochastic spatial processes and their properties, we present method for the analysis of Point Process data, Geostatistical (random surface) data and Lattice (areal) data. A brief discussion on spatial datasets and GIS will be given.
University: Firenze (il corso si svolgerà a Firenze presso DISIA)

Webpage: https://www.unifi.it/p-doc2-2019-000000-B-3f2b3a31392c2e-0.html

----

Title:
Lecturer:
Hours/ECTS:
Period:
Course presentation:
University: Firenze/Perugia
Webpage:
#
==#