Corsi Offerti per l’anno 2021/2022

Curriculum in Matematica
Curriculum in Informatica
Curriculum in Statistica

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: Functions of complex and hypercomplex variable

Lecturer: Caterina Stoppato (Università di Firenze)

Hours/ECTS: 30/6

Period: To be chosen

Course presentation: the course will focus on function theory in one (hyper)complex variable. After the necessary prerequisites about holomorphic complex functions, it will present some classical results such as the classification of Riemann surfaces, as well as some dynamics over Riemann surfaces. The course will then present the theory of regular functions of one quaternionic or hypercomplex variable, which is the subject of current research along with its applications to other areas of mathematics.

University: Firenze

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

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-doc2-0-0-A-3f2b3a2e3a2d2f.html

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Title: Strong approximation methods in group theory

Lecturer: Orazio Puglisi (Università di Firenze)

Hours/ECTS: 20/4 (to be confirmed)

Period: second semester

Course presentation: TBA

University: Firenze

Webpage: https://sites.google.com/unifi.it/oraziopuglisi/home-page?authuser=0

Title: Inverse and ill-posed problems

Lecturer: Elisa Francini, Sergio Vessella (Università di Firenze)

Hours/ECTS: between 20 and 30 hours / between 4 and 6 ECTS

Period: January-May 2022

Course presentation: TBA

University: Firenze

Webpage: http://web.math.unifi.it/users/francini/, https://www.unifi.it/p-doc2-2017-200052-V-3f2a3d2d382729-0.html

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Title: Variational Methods for Imaging

Lecturer: Simone Rebegoldi (Università di Firenze)

Hours/ECTS: 10/2

Period: February 2022

Course presentation: TBA

University: Firenze

Webpage: https://www.unifi.it/p-doc2-2019-0-A-2d2b3832352c-0.html

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Title: Spline models for data analysis

Lecturer: Costanza Conti (Università di Firenze)

Hours/ECTS: 10/2

Period: December 2021

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 (see the course “Isogeometric Boundary Element Methods” for the latter application of splines). 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, thin-plate 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 (PSplines and HPSplines, in more detail). 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

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Title: Isogeometric Boundary Element Methods

Lecturers: Alessandra Sestini and Maria Lucia Sampoli

Hours/ECTS: 20/4

Period: January-February 2022

Course presentation: the course focuses on Boundary Element Methods (BEMs) for the numerical solution of differential problems, even on unbounded domains. In particular it aims to present their recent formulation within the Isogeometric Analysis paradigm (IgA-BEMs), where splines are used for both geometric and analytical purposes, see the course “Spline models for data analysis” for a different application of splines. After necessary prerequisites about Sobolev and spline spaces, the IgA numerical discretization of Boundary Integral Equations will be considered, dealing in particular with 2D and 3D Laplace and Helmholtz problems with Dirichlet/Neumann boundary conditions. The course will be concluded by presenting a quadrature rule specific for IgA-BEMs recently developed and introducing the IgA-BEMs formulation which is the object of current research.

University: Firenze

Webpage: http://web.math.unifi.it/users/sestini/, https://docenti.unisi.it/it/sampoli-0

Title: Einstein equations in Riemannian and Kähler Geometry

Lecturers:
- Daniele Angella (Università di Firenze),
- Alexandra Otiman (Università di Firenze),
- Francesco Pediconi (Università di Firenze)

Hours/ECTS: 40 hours / 8 ECTS

Period: January-June 2022

Course presentation: inspired by General Relativity, the Einstein equations are a fundamental topic at the intersection between topology, analysis and differential geometry.

We will introduce the main problems and results concerning Einstein metrics. In the second part of the course, we will examine in depth some advanced topics. A possible plan for the course is the following:

- Preliminary notions in Riemannian geometry.
- Introduction to Einstein metrics.
- Variational approach to Einstein metrics.
- Topology of Einstein manifolds.
- Preliminary notions in complex and Kähler geometry.
- Kähler-Einstein metrics.
- Calabi-Yau theorem.
- Further topics, according to the attendee's interests.

Main reference:

- A. L. Besse, Einstein Manifolds.

Additional references:

- P. Gauduchon, Calabi's extremal Kähler metrics: An elementary introduction.
- G. Székelyhidi, An introduction to extremal Kähler metrics, Graduate Studies in Mathematics, 152, American Mathematical Society, Providence, RI, 2014.

University: Firenze

Webpage:
(DA) https://sites.google.com/site/danieleangella/
(AO) https://sites.google.com/site/alexandraotiman/
(FP) https://sites.google.com/view/francescopediconi/

Title: Mathematics, Deep Learning and Deep Reinforcement Learning

Lecturer: Maurizio Parton (Università di Chieti-Pescara)

Hours/ECTS: 30/6

Period: Summer 2022

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?

We will provide (partial) answers to the above questions by introducing Geometric Deep Learning, a theory at the same time recent and fascinating, and by illustrating recent results obtained in the realm of Algebraic Geometry with complete intersection Calabi-Yau manifolds.

I will do my best to make this course accessible to the average mathematician. In particular, no prior knowledge of DL or DRL is required. A basic knowledge in probability, algebraic geometry and/or differential geometry could provide helpful, but not essential.

University: Firenze

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

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: second semester

Course presentation: TBA

University: Perugia

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

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Curriculum in Informatica

Methods for Parallel Programming

Docente: Gervasi Osvaldo

Periodo: Secondo Semestre Febbraio-Maggio 2021 (18 ore di lezione frontale + approfondimento personale)

Modalità: On line

CFU: 6

Metaheuristics and Evolutionary Computation

Docenti: Marco Baioletti, Valentino Santucci

Periodo: Secondo Semestre Febbraio-Giugno 2021 (18 ore di lezione frontale + approfondimento personale)

Modalità: In presenza e/o online

CFU: 6

Quantum Computing

Docenti: Marco Baioletti

Periodo: Secondo Semestre Febbraio-Giugno 2021 (18 ore di lezione frontale + approfondimento personale)

Modalità: In presenza e/o online

CFU: 6

Affective Computing and Emotion Recognition

Docenti: Alfredo Milani, Valentina Franzoni

Periodo: Secondo Semestre Febbraio-Giugno 2021 (18 ore di lezione frontale + approfondimento personale)

Modalità: In presenza e/o online

CFU: 6

Blockchain technology

Docente: Stefano Bistarelli,

Periodo: Secondo Semestre Febbraio-Maggio 2021 (18 ore di lezione frontale + approfondimento personale)

Modalità: On line

CFU: 6

Advanced Algorithms
Docente: Pinotti Cristina M.
Periodo: Secondo Semestre Febbraio-Maggio 2021 (18 ore di lezione frontale + approfondimento personale)
Modalità: On line
CFU: 6

Advanced Neural Networks

Docente: Valentina Poggioni

Periodo: Secondo Semestre Gennaio-Febbraio 2021 (18 ore di lezione frontale + approfondimento personale)

Modalità: In presenza e/o online

CFU: 6

Unsupervised Anomaly-Based Intrusion Detection

Docenti: Bondavalli Andrea, Zoppi Tommaso

Periodo: Secondo Semestre Febbraio-Maggio 2021 (18 ore di lezione frontale + approfondimento personale)

Modalità: In presenza (On line se non possibile in presenza)

CFU: 6

Abstract:

Anomaly detection aims at identifying patterns in data that do not conform to the expected behaviour, relying on machine-learning algorithms that are suited for binary classification. It has been arising as one of the most promising techniques to suspect attacks or failures, as it has the potential to identify errors due to unknown faults as well as intrusions and zero-day attacks. Different studies have been devised Unsupervised Machine Learning (ML) algorithms belonging to different families as clustering, neural networks, density-based, neighbor-based, statistical, and classification. Those algorithms have the potential to detect even unknown threats thanks to a training phase that does not rely on labels in data. The talk shows how different algorithms are better suited for the detection of specific anomalies of system indicators, which manifest when attacks are conducted against a system. However, building, configuring, exercising, and evaluating anomaly detection algorithms is not trivial, as it may generate misleading results. Moreover, recent Meta-Learning techniques show promising results even with unsupervised algorithms, but are difficult to understand

and implement, stacking up even more complexity. In any case, the quality of the best solution that can be devised depends strongly on the problem at hand and demands for high cost for selecting and finding the optimal set up of unsupervised algorithms. To this end, we conclude the course by proposing a cheap method to quantitatively understand the achievable results without exercising the full optimization activities.

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Curriculum in Statistica

Elements of statistical inference
Prof. Alessandra Mattei, Agnese Panzera, Anna Gottard (UNIFI)
Hours/CFU: 10/2
When: Gennaio/Febbraio
Mandatory course for the curriculum in Statistics

Social demography: models and applications
Prof. B. Arpino, R. Guetto, E. Pirani, V. Tocchioni, D. Vignoli (UNIFI)
Hours/CFU: 15/3
When: Gennaio/Febbraio
Course description: The seminars will give an overview on current topics in the field of populations 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)

Random effects models for multilevel and longitudinal data
Prof. Leonardo Grilli, C. Rampichini (UNIFI)
Hours/CFU: 15/3
When: gennaio-febbraio
Abstract: 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.

Gaussian Mixture Models for Model-Based Clustering, Classification and Density Estimation
Prof. Luca Scrucca (UNIPG)
Hours/CFU: 10/2
When: February
Course description: Finite mixture models, Gaussian Mixture Models, Model-based clustering based on multivariate Gaussian distribution, EM algorithm, Model selection,

Density estimation via finite mixture modeling, Classification using Gaussian mixture models, Variable selection, The R package mclust

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Latent variable models for cross-section and longitudinal data
Prof. Silvia Pandolfi (UNIPG)
Hours/CFU: 10/2
When: February
Course description: The course aims at introducing the basic concepts of latent variable models for cross-section and longitudinal data. Different specifications of this class of models, according to the nature of the response variables, of the latent variables and the inclusion or not of individual covariates, will be outilined. Maximum likelihood estimation of these models, based on the Expectation-Maximization algorithm, will be presented using the R language. Prior knowledge of the fundamental concepts of statistics and probability will be assumed. In addition, a basic knowledge of the R software is required for laboratory activities.

Bayesian methods for high-dimensional data
Prof. Francesco Stingo (UNIFI)
Hours/CFU: 10/2
When: May 2022
Breve descrizione:
Bayesian approaches for model selection and inference in the context of: Linear regression, GLM, Semi-parametric regression and other topics (e.g., mixtures, graphical models), time permitting
With applications in bio-medicine, with a particular focus on genomics.

Kernel smoothing
Prof. Agnese Panzera
Hours/CFU: 10/2
When: May-June
Abstract: 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 idea to density estimation and regression problems, along with some related issues.

Introduction to causal inference
Prof. Fabrizia Mealli, Alessandra Mattei
Hours/CFU: 10/2
When: June
Course description: The potential outcome approach. The assignment mechanism. Design and analysis of randomized experiments. Design and analysis of observational studies with regular assignment mechanisms. Causal inference in irregular designs: Causal studies with

intermediate variables, Regression discontinuity designs, Causal studies where units are clustered or organized in networks. Miscellanea: Machine Learning and Causal inference; Difference-in-differences; synthetic controls; causal inference in time series setting.
Mandatory course for the curriculum in Statistics

Short course of Bayesian Causal Inference
Prof. Fan Li (Department of Statistical Science, Duke University, Durham, NC, USA)
Hours/CFU: 5 days/6CFU
When: 6-10 June 2022
Course description: 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.

Approximate Bayesian Computation (ABC)
Prof. Fabio Corradi, Cecilia Viscardi (UNIFI)
Hours/CFU: 15/3
When: June -July 2022
Course description: ABC as an explanation of how Bayes rule works. Generative models. ABC with no approximation. Examples from network analysis and Population genetics. Statistics and approximations in ABC. Rejection ABC and its convergence to exact Bayesian computation. Some limits in the use of Rejection ABC by examples. Further topics: Trade-off between degree of approximation and computational efficiency. Relevance of the prior distribution for mixing. 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 like Random Forest ABC, Selection of Statistics and Regression adjustment to be further developed by a presentation given by the students in the last lecture.

Statistical learning based on trees
Prof. Anna Gottard (UNIFI)
Hours/CFU: 15/3
When: June-July 2022
Course description: Regression and classification trees based on CART and its extensions. Bagging, Random Forest, Boosting. BART.

Fundamentals of computer science for the data scientist

Prof. M. Boreale, A. Marino, D. Merlini, M. C. Verri
Hours/CFU: 40/8
When: Spring 2023
Course description: 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.