Corsi Offerti per l’anno 2021/2022

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: Symmetry results for elliptic PDE's and analytic/geometric inequalities.
Lecturer: Alberto Roncoroni (Università di Firenze & INdAM)
Hours/ECTS: 10-15/2-3
Period: November-December 2021
Course presentation: the course will focus on the study of qualitative properties of solutions to elliptic PDE's and to analytic/geometric inequalities (such as the isoperimetric inequality, the Sobolev inequality and the Brunn-Minkowski inequality). In particular, in the first part of the course symmetry results for elliptic PDE's will be presented, while in the second part of the course some results related to classical analytic and geometric inequalities will be discussed. All the classical results will be accompanied by recent generalizations and further results (e.g. in the anisotropic setting and in the context of convex cones).
A possible plan for the course is the following:

- Preliminaries from the classical theory of elliptic PDE's.
- Symmetry results for overdetermined problems: the method of moving planes, P-functions, the duality theorem and integral identities.
- A jump in differential geometry: Alexandrov soap bubbles theorem.
- A symmetry result in the ball: a further application of the method of moving planes.
- The critical p-Laplace equation: the sharp Sobolev inequality via optimal transport and classification results.
- The optimal transport and geometric inequalities: the isoperimetric inequality and the Brunn-Minkowski inequality.

References:

1. L. Ambrosio, N. Gigli. A user's guide to optimal transport. In: Modelling and Optimisation of Flows on Networks. Lecture Notes in Mathematics, vol. 2062, pp. 1-155 Springer-Verlag (2013).
2. X. Cabré. Elliptic PDE's in probability and geometry: symmetry and regularity of solutions. Discrete Contin. Dyn. Syst. 20, no. 3 (2008), 425-457.
3. G. Ciraolo, A. Roncoroni. The method of moving planes: a quantitative approach. Bruno Pini Mathematical Analysis Seminar. 9 (2018), 41-77.
4. S. Dipierro, E. Valdinoci. Elliptic partial differential equations from an elementary viewpoint. Lecture notes (2021) arXiv:2101.07941
5. D. Gilbarg, N. S. Trudinger. Elliptic Partial Differential Equations of Second Order. Springer, Berlin (1977).
6. Q. Han, F.H. Lin. Elliptic Partial Differential Equations. Courant Lect. Notes Math., vol. 1, Amer. Math. Soc., Providence, RI, 1997.

7. R. Magnanini. Alexandrov, Serrin, Weinberger, Reilly: symmetry and stability by integral identities. Bruno Pini Mathematical Seminar. 8 (2017), 121-141.
8. C. Nitsch, C. Trombetti. The classical overdetermined Serrin problem. Complex Variables and Elliptic Equations. 63, no.7-8 (2018), 665-676.
9. M. H. Protter, H. F. Weinberger. Maximum Principles in Differential Equations. New Jersey: Prentice-Hall 1967.
10. P. Quittner, P. Souplet. Superlinear parabolic problems. Blow-up, global existence and steady states. Birkhäuser, Basel, 2007; xii+584 p.

More detailed references will be provided during the course.

University: Firenze
Webpage: https://sites.google.com/view/albertoroncoroni/home

Title: Spline models for data analysis

Lecturer: Costanza Conti (Università di Firenze)

Hours/ECTS: 10/2

Period: 10-21 Gennaio 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 (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: Matematica artificiale

Lecturers: Marco Maggesi

Period: mercoledì 19 gennaio 2022

Course presentation: Fino ad anni recenti, la Matematica era una attività svolta dagli esseri umani per gli esseri umani. Nel seminario verrà discussa una nuova prospettiva, in cui la Matematica diventa un'attività che esseri umani e macchine svolgono per esseri umani e macchine.

Title: Isogeometric Boundary Element Methods

Lecturers: Alessandra Sestini and Maria Lucia Sampoli

Hours/ECTS: 20/4

Period: 24 Gennaio - 18 Febbraio 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

Titolo: Stellati e tassellazioni dal Medioevo ad alcuni sviluppi moderni

Docente: Nicla Palladino (Università di Perugia)

Hours/ECTS: 10/2

SSD: MAT/04

Periodo: gennaio-febbraio 2022

Modalità: online

Course presentation: Nel 1619, Johannes Kepler stampava uno dei suoi grandi capolavori, l'Harmonices Mundi, in cui matematica profonda e visioni mistiche si fondevano suggestivamente. Il primo capitolo è dedicato ai poligoni regolari, tra i quali troviamo i poligoni stellati, mentre il secondo contiene una trattazione delle tassellazioni semi regolari del piano anche con figure stellate e i solidi archimedei. Questi argomenti appaiono nella storia della matematica in modo episodico: in particolare, la storia della scoperta e della definizione di poligoni e poliedri stellati inizia, in Occidente, nel Medioevo con alcuni testi latini che vengono ripresi nel Rinascimento anche da valenti matematici ma questi studi si compiono in modo organico solo con Keplero. Il corso affronta le origini e la successiva formalizzazione matematica delle figure geometriche stellate, dal loro impiego nell'arte alla definitiva matematizzazione, passando per i meno noti matematici del medioevo che contribuirono alla loro sistematizzazione teorica.

References: A. Brigaglia. Tassellazioni, solidi archimedei, poligoni stellati nell'Harmonices Mundi.
http://artmatpalermo18.altervista.org/14-docs/15-tassellazioni-solidi-archimedei-poligoni-stellati-nell-harmonices-mundi-di-keplero
A. Brigaglia, N. Palladino, M.A. Vaccaro. Historical notes on star geometries in mathematics, art and nature. In "Imagine Math 6 Between Culture and Mathematics" Editors: Emmer Michele, Abate Marco (Eds.), Springer International Publishing 2018.
J. Kepler: "Harmonices Mundi", Frankfurt, 1619.
G. Molland. Thomas Bradwardine, Geometria Speculativa. Franz Steiner Verlag Wiesbaden Gmbh, Stuttgart 1989.
S. Stevin. Problemata Geometrica, 1583.
Webpage: https://www.unipg.it/personale/nicla.palladino

Title: Teoria dell'Approssimazione

Lecturers: Laura Angeloni and Gianluca Vinti (Università di Perugia)
Hours/ECTS: 15/3
Period: January-April 2022

Course presentation: The course aims to introduce the student to the Approximation Theory, a branch of mathematics that mainly involves, but is not limited to, Mathematical Analysis and Numerical Analysis. The course will have an analytical approach and starting from the classical approximation results of the convolution operators, it will arrive at the introduction and the study of discrete sampling operators. These operators, whose applicative effects in the field of Signal and Image Processing have a considerable scope, will be studied in terms of their approximation properties in various functional spaces, such as, in addition to those of continuous and uniformly continuous functions, in L ^ p spaces, in Orlicz and modular spaces and in spaces of functions with bounded variation (BV-spaces). A brief outline of the possible applications in various fields (e.g.,
biomedical, engineering, etc.) will be provided to understand how the treated theory can be implemented to study real world problems.

A possible plan for the course is the following:

- Convolution and singular integrals: definitions, properties and approximation results in spaces of continuous functions

- Convergence and order of approximation in BV spaces

- Discrete sampling type operators: historical introduction (Shannon sampling theorem), generalized sampling operators and Kantorovich sampling operators, also seen as a mathematical model for image reconstruction

- Approximation results for sampling type operators in spaces of continuous functions, in Orlicz and modular spaces and in BV spaces.

- Outline of the possible applications to real world problems.

References
1. Angeloni, D. Costarelli, G. Vinti, A characterization of the convergence in variation for the generalized sampling series, Annales Academiae Scientiarum Fennicae Mathematica, 43 (2018) 755-767.
2. P.L. Butzer, R.J. Nessel, Fourier Analysis and Approximation I, Academic Press, New York-London, 1971.
3. C. Bardaro, P.L. Butzer, R.L. Stens, G. Vinti, Kantorovich-type generalized sampling series in the setting of Orlicz spaces, Sampl. Theory Signal Image Process, 6 (1) (2007) 29-52.
4. C. Bardaro, J. Musielak, G. Vinti, Nonlinear Integral Operators and Applications, in: de Gruyter Series in Nonlinear Analysis and Applications, vol. 9, Walter de Gruyter \& Co., Berlin,
2003
5. J. Musielak, Orlicz Spaces and Modular Spaces, in: Lecture Notes in Mathematics, 1034, Springer-Verlag, Berlin, 1983.

More detailed references will be provided during the course.

University: Perugia

Webpages: https://www.dmi.unipg.it/angeloni/ (Laura Angeloni)
https://www.dmi.unipg.it/gvinti/ (Gianluca Vinti)

Title: Inverse and ill-posed problems

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

Hours/ECTS: 30 hours / 6 ECTS

Period: January-May 2022

Course presentation:
The course will be divided into two different parts of 15 hours each.

A first part will be an introduction to inverse and ill posed problems with a special focus on the regularization of linear ill posed problems.
A second part will be taken from the course “Analisi Superiore” and will contain the theory of Cauchy Problem for PDE.

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: 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: Variational Methods for Imaging

Lecturer: Simone Rebegoldi (Università di Firenze)

Hours/ECTS: 10/2

Period: February 2022

Course presentation: Several tasks in image processing (including image restoration, image inpainting, blind deconvolution and others) are typically formulated as composite optimization problems, where the objective function is the sum of a data fidelity function, measuring the distance between the unknown object and the acquired data, plus some regularization terms or constraints, aimed at imposing some prior knowledge on the object itself. The numerical solution of these problems requires effective optimization strategies able to handle possible non-convex and non-differentiable terms, while retaining a low computational cost per iteration. In this context, proximal splitting methods have become attractive in the past few years. These methods proceed by splitting the objective function as the sum of two or more terms, and then involve each (or some of the) terms by evaluating its proximal operator. Despite their simplicity, standard implementations of these methods exhibit a slow rate of convergence towards the solution, so that acceleration techniques are required in order to improve their numerical performance.
The aim of this course is to introduce proximal splitting methods suited for the minimization of the sum of a differentiable (possibly non-convex) function plus a convex (possibly non-differentiable) term, with particular attention to proximal-gradient methods. Convergence of these methods will be analyzed, both in the convex and non-convex setting. Furthermore, we discuss some popular acceleration strategies, such as the introduction of adaptive steplengths and scaling matrices, or the use of inertial steps in the iterative procedure. Finally, we present numerical results obtained on some image restoration problems, assessing the impact of acceleration techniques and hinting at possible future developments in this field.

Course Plan:
1. The image formation model: forward and inverse problems
2. Statistical approach for Gaussian and Poisson noisy data
3. Proximal-gradient methods in differentiable and non-differentiable optimization: basic theory, variable metrics, inertial techniques, inexact evaluation of the proximal operator, non-convex problems
4. Applications in image restoration problems arising from astronomy and microscopy.

References:

1. M. Bertero, P. Boccacci, V. Ruggiero, *Inverse Imaging with Poisson Data*, IOP Publishing, 2053—2563, 2018.

2. S. Bonettini, F. Porta, M. Prato, S. Rebegoldi, V. Ruggiero, L. Zanni, *Recent Advances in Variable Metric First-Order Methods*, in Computational Methods for Inverse Problems in Imaging, Springer INdAM Series 36, 1—31, 2019.
3. A. Chambolle, T. Pock, *An Introduction to Continuous Optimization for Imaging*, Acta Numer. 25, 161—319, 2016.
4. P. Combettes, J.-C. Pesquet, *Proximal Splitting Methods in Signal Processing*, in Fixed-Point Algorithms for Inverse Problems in Science and Engineering, Springer Optim. Appl., 185—212, 2011.
5. Y. Nesterov, *Introductory lectures on convex optimization: a basic course*, Applied Optimization, Kluwer Academic Publ., Boston, Dordrecht, London, 2004.

University: Firenze

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

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Title: Spectral methods in applied mathematics

Lecturers: 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: Algebraic curves and applications to cryptography and coding theory

Lecturer: Daniele Bartoli (Università di Perugia)

Hours/ECTS: 30 hours / 6 ECTS

Period: March-May 2022

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

Webpage: https://www.unipg.it/personale/daniele.bartoli

Title: Groups and graphs for democracy: An algebraic approach to social choice theory

Lecturers: Daniela Bubboloni (Università di Firenze)

Hours/ECTS: 15/3

Period: April 2022

Course presentation:

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 and McGarvey's theorem. Tournaments and basic properties. Tournament solutions and examples. Properties of tournament solutions: anonymity, Condorcet consistency and monotonicity. General tournaments. Ranking methods and examples. Neutrality, homogeneity, symmetry, and inversion.

University: Firenze

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

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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: 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: 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

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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

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Curriculum in Informatica

Elenco Corsi Dottorato Curriculum in Informatica
AA 2021-2022

Methods for Parallel Programming (confermato)

Docente: Gervasi Osvaldo

Periodo: Secondo Semestre Febbraio-Maggio 2022 (18 ore di lezione frontale + approfondimento personale)

Modalità: On line

CFU: 6

Metaheuristics and Evolutionary Computation (confermato)

Docenti: Marco Baioletti, Valentino Santucci

Periodo: Secondo Semestre Febbraio-Giugno 2022 (18 ore di lezione frontale + approfondimento personale)

Modalità: In presenza e/o online

CFU: 6

Affective Computing and Emotion Recognition (confermato)

Docenti: Alfredo Milani, Valentina Franzoni

Periodo: Secondo Semestre Febbraio-Giugno 2022 18 ore di lezione frontale + approfondimento personale)

Modalità: In presenza e/o online

CFU: 6

Advanced Algorithms (confermato)

Docente: Pinotti Cristina M.

Periodo: Secondo Semestre Aprile-Giugno 2022 (18 ore di lezione frontale + approfondimento personale)

Modalità: On line

CFU: 6

Unsupervised Anomaly-Based Intrusion Detection
Docenti: Bondavalli Andrea, Zoppi Tommaso
Periodo: Secondo Semestre Febbraio-Maggio 2022 (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.

Experimental design and statistical models: main principles for the experimental planning; theory and case studies
Prof Rossella Berni - email: rossella.berni@unifi.it - (University of Florence)
Hours/CFU: 15/3
When: March-April 2022
Course description:
- Fundamental principles of experimental design
- The experimental design in the technological field: planning and modelling
- Split-plot design and modelling
- optimal designs
- Computer experiments

Reading list:
. 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 Science
NOTE:
1-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).

Introduction to Statistical Decision Theory
Prof Silvia Bacci (University of Florence) and Bruno Chiandotto (University of Florence)

Hours/CFU: 10 / 2
When: April-May 2022
Course description: Starting from the origins of the modern Statistics, the course frames classical and Bayesian approaches to statistical inference in a decisional perspective. Links among sample data, prior information and decisional processes are outlined, illustrating the basic concepts that characterize the Classical statistical decision theory and the Bayesian statistical decision theory. A special focus is devoted to illustrating the axiomatic basis of expected utility theory and its main empirical violations.
Program: Statistics and Decisions. Utility theory. Elicitation of the utility function. Classical statistical decision theory and Bayesian statistical decision theory. Statistics, causality, and decisions.
Webpage: Silvia Bacci: https://www.unifi.it/p-doc2-2007-0-A-2c2a382b3228.html

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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.

COMPARTMENTAL MODELS FOR THE ANALYSIS OF CONTAGION DYNAMICS: INFERENCE AND GSA
Prof. Michela Baccini and Giulia Cereda (DISIA, University of Florence)
Hours/CFU: 8/1
Period: May-July 2022
Course description: The course will provide an introduction to compartmental models for epidemic dynamics and their use for prediction and inference.
We will illustrate frequentist calibration techniques for parameters estimation and parametric bootstrap procedures for confidence intervals construction.
Special focus will be given to global sensitivity analysis (GSA) and Sobol's indexes calculation as tools to assess and characterize model uncertainties both in the phase of model construction and in the inference one.
The course will include practicals on Covid19 data.
Program: Compartmental models: structure and assumptions
Calibration
Flexible modelling (spline) of time varying parameters
Quantification of sampling variability via bootstrap
GSA and Sobol's Indexes
Erlang modified SIR and SIRD

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.

Geo-spatial methods for global health applications with focus on Disease Clustering
Prof. Annibale Biggeri
Hours/CFU: 10/3
When: September/October 2022
Course description: The ultimate goal of global health science is to improve health conditions for all people worldwide. In an increasingly interconnected world, tackling the emergence of disease outbreaks requires solutions that transcend national borders. To this end, understanding the spatial variation in disease risk and the exposure to environmental hazards has become increasingly important.
In this course, we introduce state-of-the-art methods in disease clustering and disease mapping, a sub-branch of spatial statistics whose focus is on hot spots identification and on the prediction of health outcomes and exposures within a geographical area of interest. These methods have found application in public health problems both in developing and developed countries.
Scanning for hot spots of disease cases in time and/or in space is essential part of epidemiological surveillance. In the last two days of the course we shall focus our attention on case studies of disease clustering. We will review relevant literature, highlight potentially misleading approaches and introduce update methodologies.In the first part of the course we will introduce geostatistical methods and we will review popular methods for disease mapping. In low-resource settings, household surveys are a fundamental tool to quantify the disease burden, while In developed countries, disease registries provide detailed information on individuals with a specific disease or condition. Bayesian modeling will be introduced and justified.
Specific extensions to active surveillance and high risk area profiling will be discussed. This section of the course will show the connections between the two approaches and present the course topics in a unique frame.

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.

SIMULATION METHODS

Prof. Giorgio Calzolari - (University of Florence)
Hours/CFU: 10 / 2
Period: TBA
Description: 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, C, C++, Matlab, Python, R.