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di studi superiori

Università
degli Studi
di Padova

GALILEAN SCHOOL COURSES CATALOG

CLASS OF NATURAL SCIENCES

ACADEMIC YEAR 2018-2019

Calculus

Teacher: Francesco Rossi – UniPd – francesco.rossi@math.unipd.it

Motivations.
The course introduces tools of mathematical analysis for modeling. The goal is to be able to write equations describing natural phenomena and to derive the behavior of the resulting system.

Targeted audience: First year students.

Prerequisites.
High-school mathematics: polynomials, first- and second-order equations, graph of a function.

Syllabus.
1. Introduction to mathematical modeling: models in demography, biology, engineering.
2. Infinitesimal calculus: functions, neighborhoods, the infinity, limits.
3. The derivative: intuition, definition, computation, primitives.
4. Differential equations: intuition, definition, use for modeling, existence and uniqueness, stability.
5. Models with one-dimensional differential equations: demography (Malthus, logistics, Allee), physics (evaporation, evolution of temperatures).
6. Models with higher-dimension differential equations: epidemics (SIS-SIR), population dynamics (predator-prey, competition), mechanical systems (pendulum, spring, viscosity phenomena).

Teacher CV.
I earned my Ph.D. in Applied Mathematics in 2009, jointly at SISSA Trieste, Italy and University of Burgundy, France.
I was Assistant Professor in Control Theory at University of Aix-Marseille, France, from 2010 to 2017.
Since 2017, I am Associate Professor in Mathematical Analysis at University of Padova.
My main research interests cover control theory and mathematical modeling of crowds.

Textbooks/bibliography
M Braun, C. S. Coleman, D. A. Drew, Eds. Differential Equations Models, Springer 1978.
S.H. Strogatz, Nonlinear Dynamics and Chaos: With Applications To Physics, Biology, Chemistry, And Engineering. Westview Press, Second Edition, 2014.

Complements of analysis

Teacher: Luca Martinazzi - UniPd - luca.martinazzi@math.unipd.it

Motivations.
This course takes place in the first trimester of the first year; it requires only a minimal mathematical background. The aim is to cover topics that are related to, but not usually treated in the standard first-year courses in Analysis.
Targeted audience: First-year students in Sciences or Engineering.

Syllabus.
Elementary set theory: cardinality, well-orderings, Zorn's lemma.
Elements of topology: metric spaces, compactness, Cantor sets.
Complements of sequences and sequences of functions and their convergence. Ascoli's theorem, Stone-Weierstrass theorem.
Semicontinuity, parametrized curves on surfaces, existence of geodesics.
Ordinary differential equations, fixed points and Peano's theorem.

Teacher CV.
Born in 1981.
2000-2004 Student at the University of Pisa with fellowship from Scuola Normale Superiore. 2004-2005 PhD student Stanford University. 2005-2009 PhD student at ETH Zurich. Advisor: prof. M. Struwe.
2009-2011 Junior visitor, CRM, Scuola Normale Superiore, Pisa.
2011-2013 Assistant Professor at Rutgers University, New Jersey (USA)
2013-2017 SNF Professor at the University of Basel (CH)
2017-present Associate Professor in Mathematical Analysis, University of Padova.
Research interests: Calculus of variations, geometric analysis, partial differential equations.

Textbooks/bibliography.

L. Ambrosio, C. Mantegazza, Complementi di Matematica (available online)
W. Rudin, Principles of Mathematical Analysis
M. Giaquinta, G. Modica, Mathematical Analysis, Linear and Metric Structures and Continuity, Springer.

Introduction to probability models

Teacher: Alessandra Bianchi – UniPd – alessandra.bianchi@unipd.it

Motivations.
The aim of the course is to provide an introduction to elementary probability theory and its application to sciences. The typical environment will be that of discrete probability spaces that will be introduced in the first lectures together with some basic probability tools. By the construction and the analysis of suitable models, it will then be shown how probability can be applied to the study of phenomena in physics, computer science, engineering and social sciences. In turns, this will led to the discussion of some open problems of the field.

Targeted audience.
The course will be self-consistent and no specific mathematical knowledge is required. Logic and a scientific attitude are always helpful.

Syllabus.
First elements of probability theory: Discrete probability spaces; Combinatorics; Conditional probability; The Ising model in statistical mechanics: Definition and properties; Analysis of phase transitions in dimension 1 and 2; Discrete random variables: Discrete distributions, mean value, independence; Binomial and geometric distribution; Moments generating function; Applications to two common problems: The coupon collector problem; Shuffling a deck of cards; The symmetric random walk in one and higher dimensions: Definition and properties; Reflection principle and return probability at 0; Analysis of transience and recurrence; Electrical networks and random walk on graph: Elements of discrete potential theory; Harmonic functions and their probabilistic interpretation; Random walk on general graphs; Application to the gambler's ruin problem: probability of loss and win in a gambling game; Markov chains (theory): Definition and classification of Markov chains in finite space; Stationary distribution and ergodic theorem; Markov chains (examples and applications): Eherenfest model; Bernoulli-Laplace model; Galton-Watson branching process; Elements of Monte Carlo method: Definition of Monte Carlo Markov Chain (MCMC); examples and application to optimization problems.

Teacher CV.
Born on 31/12/1977
Education and positions

- July 2003 degree in Mathematics - University of Bologna
- April 2007 PhD degree in Mathematics - University of Roma Tre
- 2007-2009 postdoc fellow at the WIAS of Berlin (Germany)
- 2010- 2012 postdoc fellow at the Mathematics Dep. of Bologna
- Since May 2012 Assistant Professor ("Ricercatore") of Probability and Statistics at the Mathematics Dep. of Padova.

Research interests: probability and Statistical Mechanics, Metastability in Markovian processes, Stochastic dynamics and relaxation time, Interacting particle systems on random structures
She published 8 articles on international journals and gave around 30 talks to students and experts of the field. Teaching: 2010&2011&2012: Probability and statistics – University of Bologna; 2012&2013&2014: Statistics – University of Padova; 2014: Introduction to Probability models- Galilean School of Padova. Since 2012, responsible of the FIRB project "Stochastic Processes and Interacting Particle Systems".

Textbooks/bibliography.
1. F. Caravenna, P. Dai Pra. *Probabilità. Un primo corso attraverso modelli e applicazioni*, Springer (2013).
2. W. Feller. *An Introduction to Probability Theory and its Applications. I Volume*, Third edition, Wiley (1968).

For consultation:
3. P. G. Doyle, J.L. Snell*. Random walks and electric networks. Carus Mathematical Monographs, 22, Mathematical Association of America (1984). Available online.*
4. D. A. Levin, Y. Peres, E. L. Wilmer, *Markov Chains and Mixing Times*, American Mathematical Society, Providence, RI (2009). Available online. 5. O. Haggstrom. Finite Markov Chains and Algorithmic Applications. Cambridge University Press (2002). Available online.

Introduction to Thermodynamics

Teacher: Fulvio Baldovin – UniPd – fulvio.baldovin@unipd.it

Motivations.
Thermodynamics is a basic interdisciplinary subject which bridges over different areas of science, including physics, mathematics, chemistry, engineering, biology, and medicine. Although common to many bachelor curricula, time constraints and needs of focusing on practical application in the specific field tend to hinder the presentation of the simple, symmetric structure which underlies Thermodynamics. As a consequence, students may turn out to be confused about the meaning and use of different thermodynamic potentials and response functions.
Goal of the present course is to introduce the thermodynamics of simple systems. While keeping mathematical aspects at a level suitable for first-year undergraduate students, emphasis will be given to the equivalence of the entropy and energy representations, which through Legendre transformations generate all other potentials. Exemplifications and case of study from different fields will help the comprehension and application the formal structure.

Targeted audience.
The course targets the Natural Science Class of the Galilean School of the University of Padova, including students in physics, mathematics, chemistry, engineering, biology, and medicine. The ideal audience has supposedly been exposed to an introductory course of mathematical analysis in one variable, while a practical knowledge of partial derivatives and Legendre transformations will be offered within the course's lectures.

Syllabus.
- The temporal nature of macroscopic measurements
- The spatial nature of macroscopic measurements
- Summary of thermodynamic parameters
- The postulate of thermodynamic equilibrium
- Walls and constraints
- Measurability of the energy
- Quantitative definition of heat
- The basic problem of equilibrium thermodynamics
- The entropy postulates
- Partial derivatives and differentials
- Intensive parameters and equations of state
- Thermal, mechanical, and chemical equilibrium
- The Euler equation
- The Gibbs-Duhem relation
- Fundamental relation and equations of state
- The simple ideal gas
- The van der Waals ideal fluid
- The electromagnetic radiation
- The “rubber band”
- Second derivatives of the fundamental relation
- Possible, impossible, quasi-static, and reversible processes
- The maximum work theorem
- Engine, refrigerator, and heat pump performance
- The Carnot cycle
- Insight: thermal conductance and conductivity
- Power output and endoreversible engines
- The energy minimum principle
- Legendre transformations
- Thermodynamic potentials
- Massieu functions
- The minimum principles for the potentials
- The Helmholtz potential and the Laplace equation
- The Gibbs potential and chemical reactions
- Maxwell relations

- Reduction of derivatives
- Reconstruction of a fundamental equation from response functions
- Thermodynamic stability in the entropy representation
- Thermodynamic stability for the potentials
- Introduction to phase transitions
- The Clapeyron equation
- Unstable isotherms and first-order transitions
- General attributes of first-order phase transitions
- Thermodynamics in the neighborhood of the critical point

Teacher CV.
Fulvio Baldovin is Assistant Professor in Physics at the Physics and Astronomy Department of the University of Padova. He is author of about 45 original research articles in international journals. He has been teaching Statistical Mechanics for the Ph.D. degree in Physics, and Biological Physics for the Bachelor degree in Molecular Biology. He has been tutor in Theoretical Physics for the Galilean School of the University of Padova. He actively collaborates with complex systems groups at the Weizmann Institute in Israel and at the Universidad Nacional Autonoma de Mexico (UNAM).

Textbooks/bibliography.
H.B. Callen, *Thermodynamics and an introduction to Thermostatistics – Second Edition*, Wiley.
A number of problems and examples will be explicitly solved at the blackboard.

Measure theory

Teacher: Paolo Ciatti – UniPd – paolo.ciatti@unipd.it

Motivations.
The course is an introduction to the Lebesgue theory of integration in Euclidean spaces. The Lebesgue integral is nowadays a standard tool in the scientific literature. It is a flexible instrument allowing the proof of powerful theorems such as the celebrated Lebesgue dominated convergence theorem. Its wide diffusion is related to the completeness of the Lebesgue spaces of functions, a result of fundamental importance not only in mathematics, but also in quantum physics.

Targeted audience.
This lecture course is particularly directed to students in Mathematics, Physics and Engineering. However, students from other scientific disciplines may take advantage of a rigorous presentation of fundamental notions from measure theory which are often assumed to be known without providing a proof. A basic course in calculus would cover all necessary prerequisites.

Syllabus.
The exterior measure and the notion of measurable sets in Euclidean spaces. Measurable functions and definition of integrals for real or complex-valued functions. The monotone convergence theorem and the dominated convergence theorem. The space of integrable functions and the Riesz-Fischer theorem. The Fubini-Tonelli theorem. The Fourier inversion formula. The space of square integrable functions. An introduction to Hilbert spaces. Applications to Fourier series. The Fourier-Plancherel transform. Differentiation of the Lebesgue integral and the Hardy-Littlewood maximal function. Approximations to the identity and more general maximal functions.

Teacher CV.
Paolo Ciatti. Undergraduate Education: Laurea in Fisica, Università di Torino,1990. Thesis directed by Prof. Tullio Regge. Graduate Education: PhD in Mathematics, Politecnico di Torino,1995. Thesis directed by Prof. Fulvio Ricci. Academic Positions: Junior Researcher, University of New South Wales (Sydney),1996-1997. Ricercatore, Università di Padova, 1998-2008. Professore Associato, Università di Padova, 2008-present. Adjoint Professor, Dalhousie University (Halifax, Nova Scotia), 2013-present.

Textbooks/bibliography.
Folland, Gerald B. *Real analysis. Modern techniques and their applications*. Second edition. John Wiley & Sons, Inc., New York, 1999.
Royden, H. L. *Real analysis.* Third edition. Macmillan Publishing Company, New York, 1988.

Supramolecular chemistry

Teacher: Paolo Scrimin – UniPd – paolo.scrimin@unipd.it

Motivations:
Supramolecular chemistry is the chemistry of the (weak) interactions between molecules leading to new entities different from the original ones. It has provided the “eyeglasses” to scientists also to understand several phenomena occurring in biological systems. Supramolecular chemistry has shown that clusters of molecules may operate in a concerted manner leading to cooperation between them (cooperativity). Cooperating molecules perform better than isolated ones in a way that is not much different from what happens to animals (and humans do not constitute an exception!). Indeed, cooperativity is the rule rather than the exception in biological systems. The course will stretch between chemistry and biology with provocative incursions in psychology and animal behavior as well.

Targeted audience:
Third year students of the Natural Science Class. Students of other classes are welcome.

Prerequisites:
Basic knowledge of chemistry and biology but material to fill the cultural gap for those lacking that knowledge will be provided.

Syllabus:
Strong and weak interactions between molecules. Couples and clusters of molecules. How to “see” molecules and the interactions between them. Supramolecules and biological molecules. Molecular recognition. Molecular sensing. Supramolecular catalysis and enzymes. Supramolecular clusters: soaps and surfactants. The mimicry of biological membranes. Nanoclusters. What is cooperativity? How do we measure it? Cooperativity between synthetic and natural molecules. Cooperativity between molecules and living seastems.

Teacher CV:
Professor of Organic Chemistry, Department of Chemical Sciences, University of Padova, Padova, Italy
Bio: Born: September, 9 1952. Doctor of Chemistry (1976). Professor of Organic Chemistry, University of Padova (since 1997)
Research topics: Nanomedicine; Gold nanoparticles as self-assembling biomimetic systems; Models of hydrolytic enzymes.
Research interests and achievements: The focus of my interests has been on molecular receptors, amphiphilic aggregates and oligopeptides in which transition metal ions play a key role both in the organization of the supramolecules and in the activation of the catalytic processes. I have developed peptide-based functional systems subject to allosteric control by metal ions quite effective in the cleavage of plasmid DNA and RNA as well. My recent interests have evolved into the field of gold nanoparticles, particularly in their use as templates for the self-assembly of cooperative molecular receptors and catalysts. I have developed the “nanozymes”, monolayer-protected nanoparticles with enzyme-like properties and saccharides passivated nanoparticles as potential nanovaccines. I have published more than 190 papers in peer reviewed journals.

Textbooks/bibliography:
Lecture notes

Fluidynamics

Teacher: Roberto Turolla - UniPD, turolla@pd.infn.it

Motivations
Fluids and their motions play a central role in many areas of physics, engineering, biology and physiology, from the scale of living cells to astronomical ones. Fluids are complex systems, the dynamics of which was (partly) understood only during the last century. The course aims at providing the basics of fluid mechanics, i.e. the dynamics of liquids, presenting at the same time a number of examples and applications.

Targeted audience
Second year students in physics, mathematics, chemistry and engineering. The course is suited also for students in life sciences with a sufficient mathematical background (only elementary notions of calculus and vector analysis are required).

Syllabus
Basic properties of fluids: pressure, density, viscosity. Newtonian and non-Newtonian fluids (interlude: how it is possible to walk on a liquid).
Conservation laws and equations of motion. The control volume and the Reynolds transport equation. The conservation of mass, the equations of momentum and energy. The Euler and Bernoulli equations.
Dimensional analysis and the similarity principle. The basic adimensional groups in fluidynamics: force and pressure coefficients, the Reynolds, Froude, Rossby and Mach numbers. Adimensional form of the equations of motion and the role of “numbers” in their analysis. Geometrical and dynamical similarity.
Ideal flows. Two-dimensional flow of an inviscid fluid. Stream function and streamlines. The velocity potential and Laplace equation. Superposition principle. Circulation. Ideal flow past a cylinder. Magnus effect. Lift: why do planes fly?
The stress tensor. Stresses in an incompressible fluid. The Navier-Stokes equations. Applications to one-dimensional flows: Poiseuille flow, fluid sheet on an inclined plane. Internal laminar flows. Flow in a conduct: critical Reynolds number and the entrance length, Poiseuille law. Flow between two plane-parallel plates: the Couette flow. Lubrication. The boundary layer for a plane surface, Blasius solution. The boundary layer for a curved surface. Viscous flow past a sphere (Stokes flow) and a cylinder. Geostrophic flows and the Ekman boudary layer.

Teacher CV
Roberto Turolla got his Master degree in Physics at the University of Padova, attended a PhD programme at the International School for Advanced Studies in Trieste and is presently full professor at the Department of Physics and Astronomy, University of Padova. Since 2007 he holds a Honorary Professorship at Mullard Space Science Laboratory, University College London (UK).
Research interests: astrophysics of compact objects (black holes and neutron stars). In particular, his expertise is in astrophysical radiative transfer under strong field (gravitational and magnetic) conditions and in the interpretation of X-ray/optical/radio data from collapsed stars in terms of physical models. Such an activity is sustained by several international collaborations with different institutions, both in Europe and the US. He published more than 190 papers on international refereed journals. He teaches General Physics for the bachelor degree in Astronomy and Relativistic Astrophysics for the master degree in Physics.

Textbooks/bibliography
J.F. Kreider *Principles of Fluid Mechanics, Allyn & Bacon*
Notes of the lectures (in pdf format)

Java programming at different abstraction levels

Teacher: Silvia Crafa – UniPd – silvia.crafa@unipd.it

Motivations The course introduces the Java programming language at different abstraction levels: from the object-oriented programming to the modern concurrent and distributed computing. Besides the underlying programming language, the course aims at developing the student's ability to reason about programs, their structure and their soundness. In this sense a number of lectures will hint at the theory of programming languages and at the social and ethical implications of modern software systems.

Syllabus

- object-oriented programming: goals, principles, implementation; elements of theory of object-oriented languages;
- concurrent programming: different models of concurrency and their challenges; thread-based programming;
- elements of distributed programming: socket and RMI;
- social and ethical implications of modern software systems: non neutrality of technology, socio-technical systems and artificial intelligence, ACM international code of ethics.

Examination method: each student will choose either given exercises, or a software project or an in-depth analysis of a specific subject.

Textbooks:

- Silvia Crafa, Oggetti, Concorrenza, Distribuzione. Programmare a diversi livelli di astrazione. Ed. Esculapio, 2014
- Core Java 2, vol. 1 and 2. Horstmann and Cornell, ed. Prentice Hall.

Algebraic Combinatorics

Teacher: Pablo Spiga --UniMib -- pablo.spiga@unimib.it

Motivations: The aim is to cover topics that are related to algebraic combinatorics and in particular to extreme algebraic combinatorics. Combinatorics is a an essential part in the human natural curiosity, but it is a subject difficult for the abstract and axiomatic way to comprehend mathematics. Typically, combinatorics appears as a collection of unrelated puzzles chosen at random. Despite this, combinatorics has an increasing importance because of its applications in computer science, statistics and algebra.

Targeted audience: This course does not need particular background and is meant for students with an interest in mathematics.

Prerequisites: No particular knowledge is required and the course is self-contained.

Teacher CV: I am definitely an algebraist and mainly a group theorist interested in symmetries. However, towards the end of my studies, I became interested also in combinatorial structures, such as graphs, designs and codes. Using my knowledge of group actions, I have been able to fully develop my second main string expertise in algebraic graph theory.
Here is a list of my research interests divided within four different areas:
Group theory: finite permutation groups, primitive groups, representations of groups, finite p-groups, groups acting on combinatorial structures.
Algebraic graph theory: vertex-transitive graphs, arc-transitive graphs, adjacency matrices, extremal configurations.
Finite geometry: generalised quadrangles, generalised n-gons.
Algebraic combinatorics: association schemes, Schur rings

Syllabus:
1) we start presenting some basic results on Ramsey theory. Ramsey theory asks questions of the form: "how many people there must be at a party in order to guarantee that, there are three people who are all either mutual friends or mutual strangers?"

To introduce formally Ramsey theory we need some basic results on graphs. We conclude this part with some rather deep number theoretic consequences such as Schur's theorem, Hales-Jewett theorem and possibly a theorem of Van der Waerden on arithmetic progressions.

2)we present the basic theory of group actions and the cycle index of the permutation group. These tools are needed to introduce the Pólya enumeration method for counting ``structures'' up to symmetries. This method is used in practise in theoretical chemistry for enumerating isomers: we give this application in the course.

3)depending on time, we present other classical topics in algebraic combinatorics: like the Erd\H{o}s-Ko-Rado theorem on maximal intersecting sets.

Textbooks/bibliography
Lecture notes and P.J.Cameron, Combinatorics: Topics, Techniques, Algorithms,
ISBN-13: 978-0521451338 ISBN-10: 0521451337

Sound and Music Computing

Teacher: Giovanni De Poli – UniPd – giovanni.depoli@unipd.it

Motivations. The course aims to provide the basis for the representation and processing of audio and music information, with particular reference to the most relevant application areas (multimedia, interfaces and virtual reality, internet, artistic creation).

Targeted audience. Third year students of the Natural Science Class. Students of other classes are welcome.

Syllabus. Fundamentals of digital audio processing. Models of audio signal and of acoustic sources. Auditory models and audio compression. Affective computing and multimodal interaction. Recognizing and communicating expressive information. Music information retrieval. Multimedia archives. Computational methods for artistic creation: music performance, theatre and dance, live electronics, sound design.

Teacher CV.
Giovanni De Poli has been a full professor of Computer Engineering at the Department of Information Engineering of the University of Padova, where he taught classes of "Data and Algorithms" and "Sound and Music Computing". He has been scientific responsible of the research group “Centro di Sonologia Computazionale” of the Dept. of Information Engineering. His main research interests are in algorithms for sound analysis and synthesis, models for expressiveness in music, multimedia systems and human-computer interaction, preservation and restoration of audio documents.

Textbooks/bibliography.
F. Avanzini, G. De Poli, *Algorithms for sound and music computing*. Padova. Available online.
U. Zoelzer (ed.), *DAFX Digital audio effects,* 2nd edition. London: John Wiley & Sons, 2011.
V. Lombardo, A. Valle, *Audio e multimedia* (4a edizione). Milano: Apogeo, 2014.

Info: https://elearning.dei.unipd.it/course/view.php?id=3918

Probabilistic methods in data analysis

Teacher
Giulio D'Agostini, Università di Roma La Sapienza
https://www.roma1.infn.it/~dagos/
giulio.dagostini@roma1.infn.it

Motivations
The course will focus on probabilistic reasoning and its applications in data analysis in order to infer model parameters (e.g. 'fits'), to compare models and to make probabilistic predictions.
Extensive use of graphical models will be made, i.e. of models which describe the network of causes and effects.
Practical aspects of probabilistic computation will be covered, including methods based Markov Chain Monte Carlo.
Many example will be made, using the R language as the 'lingua franca' of the course, although the use of some free (or demo version of) packages for special purposes will be illustrated (like e.g. WingBUGS, Jags and AgenaRisk).

Targeted audience
Second year students, which are assumed to have followed "Introduction to probabilistic models" during the first year.

Syllabus
Uncertainty and probability in the Sciences.
ISO Guide on Uncertainty (GUM).
Basic rules of probability for discrete and continuous variables.
Summaries of distributions and general theorems.
Bernoulli process and related distributions: Geometric, Pascal and Binomial. Poisson process and related distributions: Poisson, Exponential, Erlang. Gaussian ('normal') distribution, its importance and related distributions.
Multivariate distributions, in particular normal multivariate, including conditioning in many dimensions.
Direct sampling with Montecarlo (MC) methods.
Propagation of uncertainties: from exact to approximate methods.
Probabilistic inference. Parametric inference applied to basic models. Beta and Gamma distributions and their use in inference.
Treatment of uncertainties due to systematics. Bayesian Networks as conceptual and practical tools. Computational issues in probabilistic inference overcome by MC sampling: importance sampling; Metropolis(-Hasting) algorithm; Gibbs sampler; simulated annealing; nexted sampler.
Recovery of 'standard formulae' as special cases of the general probabilistic approach under well stated conditions.

Teacher C.V.
Giulio D’Agostini is associate professor at the University of Rome La Sapienza.
He has collaborated in large experiments at CERN (Geneva), DESY (Hamburg) and LNF (Frascati), and he is presently member of NA62 and of KLOE.
His expertise range on various aspects of the construction and the operation of detectors, and on the analysis of the resulting data.
Physics topics to which he has contributed include: study of the force between quarks and gluons; quark fragmentation; heavy quark decays; proton and photon structure function; search of new particles and phenomena, such as dibaryons, excited quarks, supersymmetric particles, electron compositeness and Higgs boson.
He is also interested in the fundamental aspects of probability theory, as well in its teaching and its applications in data analysis and in decision making processes.

Textbooks/bibliography
Mainly freely available resources, including teacher's notes and preprints
(see e.g. https://www.roma1.infn.it/~dagos/prob+stat.html).

Path Integral and Quantum Mechanics

Teacher: Massimo Passera - Istituto Nazionale di Fisica Nucleare, Sezione di Padova - passera@pd.infn.it

Motivations: The aim of the course is to introduce the path integral approach to quantum mechanics.

Targeted audience: third year students.

Syllabus:
- The path integral formalism: Introducing the path integrals. The properties of the path integrals. Path integrals as determinants. Operator matrix elements.
- Functional and Euclidean methods: The functional method. Euclidean path integral. Perturbation theory.
- The semiclassical approximation: The semiclassical propagator. The fixed-energy propagator.
- Instantons: Introduction. Instantons in the double well potential.
- Interaction with an external electromagnetic field (selected topics).

Teacher CV: Degree in Physics at University of Torino, Italy; Ph.D. at New York University, New York, USA; Postoctoral Fellow at the Institut for Theoretical Physics, University of Bern, Switzerland, at the Department of Theoretical Physics, University of Valencia, Spain, and at the Dipartimento di Fisica, University of Padova, Italy. Senior Researcher of the Istituto Nazionale di Fisica Nucleare, Sezione di Padova, Italy.

Textbooks/bibliography:
R. P. Feynman, Quantum Mechanics and Path Integrals, McGraw-Hill, 1965;
R. Rattazzi, The Path Integral Approach to Quantum Mechanics, 2009, Lecture Notes.

Elliptic curves

Teachers.
Remke Kloosterman– UniPd – remke.kloosterman@unipd.it,
Matteo Longo– UniPd – matteo.longo@unipd.it

Motivation.
The aim of this course is to give an introduction to the arithmetic theory of elliptic curves. This is a central topic in number theory, for at least two reasons. First, many recent results and open problems in number theory are directly related to the arithmetic of elliptic curves.
Some of these interactions are quite basic, whereas others (Fermat's last Theorem and the Birch and Swinnerton-Dyer conjecture) are incredibly deep.
Secondly, the theory of elliptic curves furnishes a rich class of examples which can be adapted in many different arithmetic contexts (e.g. Galois representations, p-adic Hodge theory, L-functions, modular forms….).

Target audience.
Students of the fourth and fifth year (Laurea Magistrale).

Prerequisites.
Linear Algebra, Galois Theory, Introduction to plane algebraic curves.

Syllabus.
(1) Review of affine and algebraic varieties, especially the geometry of plane curves.
(2) The geometry of elliptic curves: the Weierstrass equation; the group law; isogenies; the Tate module; the endomorphism ring.
(3) Elliptic curves over the complex numbers: elliptic curves as complex tori; complex uniformization using Weierstrass p-function.
(4) Elliptic curves over finite fields: Weil estimates; the endomorphism ring.
(5) Elliptic over and local fields: introduction to local fields, formal groups, good and bad reduction.
(5) Elliptic curves over global fields: The Mordell-Weil Theorem.
(6) L-function of elliptic curves: definitions; relation with modular forms.
(7) The Birch and Swinnerton-Dyer conjecture: statement; known results.

Teacher CV.
Remke Kloosterman
2001-2005. PhD student, Instituut voor Wiskunde en Informatica, University of Groningen.
2005-2009. Postdoc, Institut für Algebraische Geometrie, Leibniz Universität Hannover.
2009-2016. Juniorprofessor, Institut für Mathematik, Humboldt Universität zu Berlin.
2016—. Professore associato confermato. Dipartimento di Matematica, Padova.
Research interests: Algebraic geometry and Number theory. Especially the use of algebraic and geometric techniques in Number Theory.
Matteo Longo.
2000-2004. Dottorato di ricerca, Dipartimento di Matematica, Padova.
2006-2009. Ricercatore universitario, Dipartimento di Matematica, Milano Statale.
_2009-2015. Ricercatore universitario confermato, Dipartimento di Matematica, Padova.
2015—. Professore associato confermato, Dipartimento di Matematica, Padova.
Research interest: Algebraic Number Theory, especially the Arithmetic theory of Elliptic Curves and Modular Forms, and their associated L-functions.
Textbook:
J. Silverman, The Arithmetic of Elliptic curves, GTM 106, Springer, 1986.

Digital design for Additive Manufacturing and 3D Printing

Teacher: Gianpaolo Savio – UniPd – gianpaolo.savio@unipd.it

Motivations.
Additive manufacturing is an emerging technology based on joining materials to make objects from 3D model data. This course aims at providing the basics of additive manufacturing technologies with a strong emphasis on software, tools and methods for modeling and design.

Targeted audience.
The course targets the Natural Science Class of the Galilean School of the University of Padova. The course will be self-consistent.

Prerequisites.
No specific knowledge is required.

Syllabus.
Introduction and Basic Principles.
The AM process: from CAD to post-processing.
Materials and technologies for AM.
CAD models and meshes.
Slicing, hatching, pre-processing and 3D printing in practice.
Software tools for AM.
Fundamentals of surface modeling: NUBS, properties, analysis, editing and approaches (e.g. loft, sweep, continuity, curvature, transformation).
3D scanning and reverse engineering.
Volumetric modeling.
Custom implementations in CAD software.
Editing and writing Gcode.
Design for Additive Manufacturing.
Lattice structures and topology optimization.
Process simulation.

Teacher CV.
Gianpaolo Savio is assistant professor in “Design Tools and Methods for Industrial Engineering” (ING-IND/15) at the University of Padua since 2015. His research focuses on methods for Computer-Aided Design especially for free-form surfaces in many fields such as biomedical, additive manufacturing, ophthalmic, naval and geometric product specifications. On these topics, he works at a number of funded research projects as principal investigator or contributor.
Gianpaolo Savio is active in the research community where he serves as reviver for 10 international journals, as committee member or reviewer of international conferences, as member of scientific organizations and as author with more than 50 publications in international journals and conferences, some of which were awarded.
Gianpaolo Savio graduated in Mechanical Engineering in 2004 at the University of Padua. In 2008 he obtained the PhD in Design and Methods for Industrial Engineering at the University of Bologna.
From 2008 to 2015 he was a Research Assistant at the University of Padua and at the University of Ferrara.
Since 2007 he teaches "Engineering drafting", "Technology and Technical Drawing", "Image processing for industrial design" and "Geometric modeling of mechanical systems" at the University of Padua. He was supervisor and tutor of many undergraduate, graduate and doctoral theses.

Textbooks/bibliography.
Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing. Ian Gibson, David Rosen and Brent Stucker.
Notes of the lectures

For consultation.
Geometric Modeling. M. E. Mortenson
Software Solutions for Rapid Prototyping. Ian Gibson
The 3D Printing Handbook: Technologies, design and applications. Ben Redwood, Filemon Schöffer & Brian. Garret

Software.
Repetair Host/Cura/Slic3r
Rhinoceros/Grasshopper/Python
Netfabb

Frontiers in Modelling and Data Analysis In Neuroscience

FRONTIERS IN MODELLING AND DATA ANALYSIS IN NEUROSCIENCE I

Teacher

Chris Mathys, SISSA, Trieste

Motivation

This course aims to introduce students to the computational modelling of learning and inference in the brain. In order to be successful at surviving and reproducing in an often hostile environment, animals, including humans, make use of their brain to infer and predict states of their environment. We will look at how this process can be described mathematically and tied to the underlying physiology of the brain. Furthermore, we will look at how inference and learning can go wrong in the case of psychosis and other mental disorders.

Targeted Audience

Students of any background interested in neuroscience and mathematical modelling.

Prerequisites

Some calculus, linear algebra, and probability.

Syllabus

The Helmholtzian brain, inference, and learning

- Perception as inference
- Bayesian inference
- Reduction of Bayesian inference to mean updating

Some history of ideas

- The input-output paradigm
- The feed-forward filter
- Helmholtz
- Gregory
- Mumford
- Conant & Ashby
- Hinton
- Dayan
- Friston

Predictive coding

- Rao & Ballard
- Experimental evidence

Hierarchical Gaussian filtering

- The learning rate problem in volatile environments
- Derivation of the HGF
- Modular building of HGF models
- Empirical results

Modelling approaches to psychosis

- Phenomenology of psychosis
- Imperviousness to illusions
- Precision mismatch
- NMDA receptor antagonists

- Serotonergic agonists
- Cannabinoids
- Dopaminergic agonists
- Sensory deprivation
- Dreaming

Teacher CV

Chris Mathys is Assistant Professor of Neuroscience at Scuola Internazionale Superiore di Studi Avanzati (SISSA) in Trieste, Italy. He has an MSc in Interdisciplinary Sciences and a PhD in Information Technology from ETH Zurich and an MSc in psychology and psychopathology from the University of Zurich. During his graduate studies, he developed the hierarchical Gaussian filter (HGF), a generic hierarchical Bayesian model of inference in volatile environments. Based on this, he develops and maintains the HGF Toolbox, a Matlab-based free software package for the analysis of behavioural and neuroimaging experiments. Research in his group is focused on the computational modelling of inference, learning, and action as they are implemented in the brain, with a particular focus on the role of neuromodulators. A key feature of this modelling is the reduction of Bayesian inference to updates driven by precision-weighted prediction errors, which has enabled the development of hierarchical models of message passing which are able to describe inferential failures giving rise to psychopathology.

FRONTIERS IN MODELLING AND DATA ANALYSIS IN NEUROSCIENCE II

Teacher

Romain Brasselet, Language Learning and Reading Lab, SISSA, Trieste

Motivation

The aim of the course is to acquaint students with modern issues in cognitive neuroscience and the modern mathematical and statistical tools currently used by scientists involved in the field, from the psychophysical to the neuronal level.

Targeted Audience

Students of any background interested in neuroscience and mathematical modelling.

Prerequisites

Some linear algebra, basic notions in probability and statistics.

Syllabus

- Reminder on probability. Probability distributions. Central Limit Theorem.

- The Road to Linear Mixed-Effect Models.
Dealing with repeated and correlated measures in linear models. Simple Regression. Maximum likelihood estimation. Links with Pearson’s correlation, Student t-test, ANOVA. Stein’s paradox. Regularization. Fixed effect vs random effect. Mixed-effects models. Applications.

- Information Theory and Neural Coding.
The problem of neural coding. Rate coding vs temporal coding.
Introduction to Information Theory. Information Theory and decoding.

Teacher CV

2006-2007: Master in Theoretical Physics from the University Aix-Marseille 2.
2007-2010: PhD in Computational Neuroscience in 2010 at Université Pierre et Marie Curie on neural coding in the human somatosensory system.
2011-2012: Postdoc at the Max-Planck Institute for Biological Cybernetics with Christoph Kayser, Stefano Panzeri and Nikos Logothetis on the neural coding in the monkey auditory cortex.
2012-2013: Postdoc in Gustavo Deco’s group at Universitat Pompeu Fabra in Barcelona.
2013-2017: Independent postdoc at SISSA in Trieste working in collaboration with Mathew Diamond and Alessandro Treves.
2017- : postdoctoral position in the Language Learning and Reading Lab led by Davide Crepaldi.

Textbooks

Data analysis using regression and multilevel/hierarchical models. Gelman & Hill (2006).
Spikes: exploring the neural code. Bialek, de Ruyter van Steveninck, Rieke & Warland (1999).
Elements of information theory. Cover & Thomas (2012).

Geometric methods of theoretical physics

Teacher: Gianguido Dall'agata – UniPD – gianguido.dallagata@unipd.it
Luca Martucci – UniPD – luca.martucci@unipd.it

Syllabus.
Geometric methods of theoretical physics I - G. Dall'agata - 20 ore
Elements of group theory:
- Groups, subgroups, quotients and products
- Representations
- Homotopy groups
- Lie Groups
- Homogeneous spaces and their differential properties

Physical applications:
- Sigma models, pions and skyrmions
- Fiber bundles and gauge theories
- Monopoles and dyons

Geometric methods of theoretical physics II - L. Martucci - 10 ore
Instantons and nonperturbative effects:
- Instantons in quantum mechanics [double well and periodic potentials, bounces and unstable states, supersymmetric models]
- Vacuum structure of gauge theories
- Instantons in gauge theories in various dimensions
- Decay of metastable vacua in field theory