Doctoral Course in Mathematical Sciences
Department of Mathematics
University of Padova

Doctoral Course in Mathematical Sciences

Catalogue of the courses 2018

Updated January 15, 2018
INTRODUCTION

This Catalogue contains the list of courses offered to the Graduate Students in Mathematical Sciences for the year 2017-18. The courses in this Catalogue are of two types.

1. Courses offered by the Graduate School. This offer includes courses taught by internationally recognized external researchers. Since these courses might be not offered again in the near future, we emphasize the importance for all graduate students to follow them.

2. Some courses selected from those offered by the Graduate School in Information Engineering of the University of Padova, by the Master in Mathematics, and by other institutions, that we consider of potential interest for the students in Mathematics.

We underline the importance for all students to follow courses, with the goal of broadening their culture in Mathematics, as well as developing their knowledge in their own area of interest.

REQUIREMENTS FOR GRADUATE STUDENTS

Within the first two years of enrollment (a half of these requirements must be fulfilled within the first year) all students are required to follow and pass the exam of

- at least 2 among the courses called "Courses of the School" in this catalogue;
- other courses for a total commitment of at least 56 additional hours.

Students are warmly encouraged to take more courses than the minimum required by these rules, and to commit themselves to follow regularly these courses. At the end of each course the teacher will inform the Coordinator and the Secretary on the activities of the course and of the registered students.

Students must register to all courses of the Graduate School that they want to attend, independently of their intention to take the exam or not. We recommend to register as early as possible: the Graduate School may cancel a course if the number of registered students is too low. If necessary, the registration to a Course may be canceled.

Courses for Master of Science in “Mathematics”

Students have the possibility to attend some courses of the Master of Science in Mathematics and get credits for the mandatory 56 hours.

The recommendation of these courses must be made by the Supervisor and the amount of credits is decided by the Executive Board.

Courses attended in other Institutions

Students are allowed to take Ph.D. courses offered by PhD Programs of other Universities or in Summer Schools. Acquisition of credits will be subject to approval of the Executive Board.

Seminars

All students must attend the Colloquia of the Department and participate in the Graduate Seminar (“Seminario Dottorato”). They are also encouraged to attend the seminars of their research group.
HOW TO REGISTER AND UNREGISTER TO COURSES

The registration to a Course must be done online.
Students can access the online registration form on the website of the Doctoral Course http://dottorato.math.unipd.it/ (select the link Courses Registration), or directly at the address http://dottorato.math.unipd.it/registration/.
In order to register, fill the registration form with all required data, and validate with the command “Register”. The system will send a confirmation email message to the address indicated in the registration form; please save this message, as it will be needed in case of cancellation.

Registration to a course implies the commitment to follow the course.

Requests of cancellation to a course must be submitted in a timely manner, and at least one month before the course (except for courses that begin in October and November) using the link indicated in the confirmation email message.

REQUIREMENTS FOR PARTICIPANTS NOT ENROLLED IN THE GRADUATE SCHOOL OF MATHEMATICS

The courses in this catalogue, although part of activities of the Graduate School in Mathematics, are open to all students, graduate students, researchers of this and other Universities.
For reasons of organization, external participants are required to communicate their intention (loretta.dallacosta@unipd.it) to take a course at least two months before its starting date if the course is scheduled in January 2018 or later, and as soon as possible for courses that take place until December 2017.
In order to register, follow the procedure described in the preceding paragraph.
Possible cancellation to courses must also be notified.
Courses of the School

1. Prof. Giovanni Alberti
   Introduction to Geometric Measure Theory S-1

2. Prof. Giovanni Colombo
   An introduction to set-valued analysis and control theory S-3

3. Prof. Alberto Facchini
   Module Categories S-4

4. Prof. Lothar Reichel
   Numerical Linear Algebra for Ill-Posed Problems S-5

5. Prof. Paolo Rossi
   Moduli spaces of curves and integrable systems of PDEs S-6

Courses of the “Computational Mathematics” area

1. Prof. Paolo Dai Pra, Dott. Marco Formentin
   Basics in stochastic simulation MC-1

2. Dott. Luigi De Giovanni, Prof. Marco di Summa
   Optimization methods for large-scale problems MC-2

3. Prof. Massimo Fornasier
   Mean-field control and new types of games MC-3

4. Prof. Jacek Gondzio
   Interior Point Methods for Very Large Scale Optimization MC-4

5. Prof. Leszek Plaskota
   Approximation and complexity MC-5

6. Prof. Tiziano Vargiolu
   Topics in Stochastic Analysis MC-6

Courses of the “Mathematics” area

1. Prof. Cristina Acciarri
   On Lie ring methods in group theory M-1

2. Dott. Annalisa Cesaroni, Dott. Marco A. Cirant
   Variational Mean Field Games M-3

3. Prof. Massimo Fornasier
   Mean-field control and new types of games M-4
4. Dott. Laetitia Giraldi, Dott. Marta Zoppello
   Geometric Control Theory And Self-Propulsion In Fluids M-5

5. Prof. Luc Illusie
   Revisiting the de Rham-Witt complex M-6

6. Prof. Alexey Karapetyants
   Partial Differential Equations of Mathematical Physics M-7

7. Prof. Remke Kloosterman
   Compact complex surfaces M-8

8. Prof. Leonid Positselski
   Contramodules and their applications in commutative algebra M-9

9. Prof. Laura Spinolo
   Systems of conservation laws in one space variable M-10

10. Prof. Jean-Baptiste Teyssier
    Linear differential equations and Stokes structure M-11

Courses offered within the Masters’s Degree in Mathematics

1. Offered Courses MD-1

Other courses suggested to the students

1. Advanced topics in stochastic processes
   (Proff. J. Grilli, A. Maritan, S. Suweis) EC-1

2. Other suggested Courses EC-2

Courses in collaboration with the Doctoral School on “Information Engineering”

1. Prof. Ruggero Carli et al.
   Model Predictive Control DEI-1

2. Proff. Fernando De Terán, Michael Karow
   Applied Linear Algebra DEI-2

3. Prof. Giorgio Maria Di Nunzio
   Bayesian Machine Learning DEI-3

4. Prof. Lorenzo Finesso
   Statistical methods DEI-5

5. Prof. Fabio Marcuzzi
   Computational Inverse Problems DEI-6

6. Prof. Gianluigi Pillonetto
   Applied Functional Analysis and Machine Learning DEI-7
Courses of the School
Introduction to Geometric Measure Theory

Prof. Giovanni Alberti

1Università di Pisa, Dipartimento di Matematica
Email: giovanni.alberti@unipi.it

Timetable: 22-24 hours. March-May, 2018, Torre Archimede

Course requirements: Integration theory (with respect to arbitrary measures), basic notions of Functional Analysis

Examination and grading:

SSD: MAT/05

Aim:

Course contents:
The first part of the course is an introduction to some of the fundamental notions of Geometric Measure Theory having applications in several parts of Mathematical Analysis: Hausdorff measures and Hausdorff dimension, area formula, rectifiable sets. In the second part of the course a more specialized topic will be treated, namely, the theory of integral currents, which will be seen from the viewpoint of the Plateau problem (existence of minimal surfaces with prescribed boundary); this part will be preceded by a detailed presentation of the needed multilinear algebra notions.

Detailed program [topics between brackets might be skipped for time reasons]

- Review of the possible approaches to the Plateau problem
- Hausdorff measure and Hausdorff dimension
- [Hausdorff and capacitary dimensions, Frostman lemma]
- [Covering theorems and applications]
- [Self-similar fractals]
- Lipschitz functions, Rademacher theorem (via Sobolev spaces)
- Area formula
- [First variation of the area]
- [Coarea formula]
- Rectifiable and purely unrectifiable sets
- Tangent space to a rectifiable set
- Rectifiability criteria
• k-vectors and k-covectors, simple k-vectors and their geometric interpretation
• k-forms, orientation of submanifolds, Stokes theorem
• Definition of currents, boundary and mass
• Normal, rectifiable, integral and polyhedral currents
• Statement of Federer-Fleming compactness theorem
• Solution to the Plateau problem in the framework of integral currents
• [Basic regularity for minimal currents]
• Operations on currents: product, push-forward, cone on a given current
• Constancy lemma
• Flat norm and properties
• Polyhedral deformation theorem
• [Isoperimetric inequality]
• [Characterization of integral currents by slicing]
• [Boundary rectifiability theorem]
• [Proof of Federer-Fleming compactness theorem]
An introduction to set-valued analysis and control theory

Prof. Giovanni Colombo

1Università di Padova, Dipartimento di Matematica
Email: colombo@math.unipd.it

Timetable: 24 hours. First lecture on October 12, 2017 (dates already fixed, see the calendar), Torre Archimede, Room 2BC/30.

Course requirements: Basics in Real and Functional Analysis and in Ordinary Differential Equations

Examination and grading: Oral exam on the material covered in the course

SSD: MAT/05

Aim:

Course contents:

Measurability and continuity concepts for set-valued maps (Hausdorff upper and lower semicontinuity); examples of measurable and semicontinuous maps. The selection problem: measurable and continuous selections; existence results and counterexamples.


Module Categories

Prof. Alberto Facchini

1Università di Padova, Dipartimento di Matematica
Email: facchini@math.unipd.it

Timetable: 20-24 hours. First lecture on January 22, 2018, 11:00 (dates already fixed, see the calendar), Torre Archimede, Room 2BC/30.

Course requirements: Elementary notions of rings and modules
(Diciamo il contenuto del mio corso di algebra al primo anno di laurea magistrale.)

Examination and grading:

SSD: MAT/02

Aim: This course provides an introduction to some notions of rings, modules and categories.

Course contents:
Goldie dimension of lattices and modules
Dual Goldie dimension of a module
Semilocal rings
Local morphisms
Modules with semilocal endomorphism rings
Preadditive categories
Ideals in a preadditive category
The Krull-Schmidt property
Annihilating a class of objects
Semilocal categories
The spectral category of a Grothendieck category
Nonsingular modules
The functor P and its right derived functors
First applications of spectral categories
Finitely copresented objects
The dual construction to the construction of the spectral category
Applications of the category \(\text{mod-}R'\)
Finitely presented modules over a semilocal ring
Numerical Linear Algebra for Ill-Posed Problems

Prof. Lothar Reichel

1 Department of Mathematical Sciences, Kent State University, OH, USA
Email: reichel@math.kent.edu

Timetable: 24 hours, May or June 2018, Torre Archimede,

Course requirements: No special requirement is needed for this course. Only some fundamental knowledge of numerical analysis, but it could be acquired simultaneously with the lectures.

Examination and grading: Grading is based on home work or a written examination or both.

SSD: MAT/08 Numerical Analysis

Aim: The aim of this course is to introduce Ph.D. students to numerical linear algebra required for the solution of linear discrete ill-posed problems. These problems arise for instance in image restoration and from the discretization of ill-posed problems, such as Fredholm integral equations of the first kind. The singular values of the matrix of linear discrete ill-posed problems "cluster" at the origin. In particular, the matrices that arise are severely ill-conditioned and may be singular. The right-hand side represents available data that may be contaminated by measurement errors. Due to the ill-conditioning of the matrix and error in the data, straightforward solution does not give a meaningful result. Therefore regularization is employed before solution. Regularization replaces the given linear discrete ill-posed problem by a nearby problem that is less sensitive to errors in the data. Tikhonov regularization, truncated singular value decomposition, truncated generalized singular value decomposition, and truncated iteration are the most popular regularization methods. The course will discuss these method and techniques for determining a suitable value of the regularization parameter.

Course contents:

1. Linear discrete ill-posed problems Definition, properties, applications
2. Solution methods for small to moderately sized problems Regularization, Tikhonov regularization, the singular value decomposition, the generalized singular value decomposition, choice of regularization matrix
4. lp-lq minimization for image restoration.
Moduli spaces of curves and integrable systems of PDEs

Prof. Paolo Rossi

1Institut de Mathématiques de Bourgogne, Université de Bourgogne, Dijon (France)
Email: paolo.rossi@u-bourgogne.fr

Timetable: 24 hours. May-June 2018, Torre Archimede

Course requirements: The course is a priori addressed to any PhD student. Depending on the students’ background, a quick recall of differential geometry might be needed at the beginning (vector bundles and some algebraic topology, in particular cohomology and characteristic classes). The language will be as basic as possible and notions of algebraic geometry will be introduced but not assumed.

Examination and grading: Seminar

SSD: MAT/02 MAT/03

Aim: This course contains a first part of general culture on the algebraic/holomorphic geometry of Riemann surfaces (complex manifolds of dimension one, which are ubiquitous objects in both geometry and mathematical physics), close in spirit to the book “Riemann Surfaces” by Farkas and Kra, followed by a more expository part on the construction and properties of the Deligne-Mumford moduli space of stable curves (the space that classifies all stable Riemann surfaces). The idea is to present this space as an ideal algebraic geometric “botanical garden”, at the same time accessible to non-geometers (thanks also to the holomorphic language), but rich enough to try our hand with techniques like intersection theory and the Riemann-Roch theorem, without loosing ourselves in the wider generality of general varieties/schemes/stacks.

This material will give us the language needed for a short final part, monographic in nature, presenting some remarkable connections between geometry and mathematical physics. The precise topic of this last part can be chosen among several possibilities, depending on the interests and preferences of students. An example might be to state and understand the Witten-Kontsevich theorem, which forms a fascinating bridge between the topology of the moduli space of curves and the modern theory of integrable systems of PDEs.

Course contents:
- Recall of complex/holomorphic differential/algebraic geometry
- Geometry of Riemann surfaces (an overview including basic topology, the Riemann-Hurwitz formula, harmonic, holomorphic and meromorphic differentials, periods, divisors, the Riemann-Roch theorem, Jacobians, the Abel-Jacobi map, hyperelliptic curves, uniformization)
- Moduli spaces of smooth Riemann surfaces of genus 0 and 1
- Complex orbifolds
- Construction of moduli spaces of curves of any genus
- Stable curves and the Deligne-Mumford compactification
- Cohomology of the moduli space, natural cohomology classes, tautological ring
- Witten-Kontsevich theorem on intersection of psi classes and KdV equation
- Cohomological field theories
- Integrable systems from cohomological field theories
Courses of the “Computational Mathematics” area
Basics in stochastic simulation

Prof. Paolo Dai Pra¹, Dott. Marco Formentin²

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Dipartimento di Matematica
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²Università degli Studi di Padova
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Course requirements: The course assumes basic knowledge of probability theory. Additional necessary notions will be introduced during the course.

Examination and grading: Oral exam

SSD: MAT/06 Probability and Mathematical Statistics

Aim: Nowadays the ability to simulate stochastic models is a fundamental tool in many applied fields ranging from finance to biology, physics and complex systems. Moreover, to design efficient algorithms to simulate a stochastic object can be challenging and it is an active research topic by itself. The course intends to cover the basic theory of stochastic simulation along with some applications. Part of the course will be devoted to exercise sections where the students are invited to apply simulation techniques to examples.

Course contents: A tentative program can be:

1. Markov Chain Monte Carlo Methods.
2. Simulation of Stochastic Differential Equations.
4. Rare-event simulation.
Optimization methods for large-scale problems

Dott. Luigi De Giovanni¹, Prof. Marco Di Summa²

¹Università degli Studi di Padova
Dipartimento di Matematica
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²Università degli Studi di Padova
Dipartimento di Matematica
Email: disumma@math.unipd.it

**Timetable:** 16 hrs. First lecture on May 7, 2018, 11:00 (dates already fixed, see the calendar), Torre Archimede, Room 2BC/30.

**Course requirements:** Although some basic notions in optimization will be recalled, some preliminary knowledge in linear optimization might be useful.

**Examination and grading:** Written exam.

**SSD:** MAT/09.

**Aim:** Presenting the most common methods used to deal with optimization problems involving a large number of variables and/or constraints.

**Course contents:**
We discuss optimization techniques for large-scale problems, i.e., problems with a huge number of variables and/or constraints. Both discrete and continuous problems are considered. Most of the techniques that we present are based on decomposition approaches. We focus on theoretical, algorithmic, and practical aspects. The following topics will be covered (but changes are possible depending on the interests of the audience):
- review of linear continuous and discrete optimization;
- row- and column-generation techniques;
- decomposition techniques, including Dantzig-Wolfe and Benders decomposition;
- examples and applications.
Mean-field control and new types of games

Prof. Massimo Fornasier

Technische Universität München, Fakultät für Mathematik, München, Germany
Email: massimo.fornasier@emat.tum.de


Course requirements:

Examination and grading:

SSD: MAT/05, MAT/06, MAT/08

Aim:

Course contents:
This series of informal lectures presents novel results on modeling, control, and game playing of multi-agent dynamics. We focus in particular on three topics:

- sparse control, i.e., steering a large group of interacting agents by influence parsimoniously only few of them;
- mean-field control, i.e., the control of the mean-field equations describing the evolution of the probability distribution of a large population of agents;
- mean-field differential and evolution games.

The lecture series starts with basic results and it requires knowledge of relatively standard functional analysis (mainly basics of metric and Banach spaces and Bochner integration).

The analysis content of the lecture series follows:

- Existence and uniqueness solutions of the Caratheodory differential equations
- Classical examples of multiagent dynamics
- Wasserstein distances and optimal transport
- Existence and uniqueness of mean-field equations
- Introduction to optimal control and first order optimality conditions
- Introduction to Gamma-convergence
- Sparse stabilization and optimal control of multiagent dynamics
- Smooth relaxation of sparse mean-field optimal control
- Sparse mean-field optimal control
- Mean-field Pontryagin maximum principle
- Mean-field differential games
- Mean-field evolution games
Interior Point Methods for Very Large Scale Optimization

Prof. Jacek Gondzio

School of Mathematics, University of Edinburgh, UK
http://www.maths.ed.ac.uk/~gondzio/
Email: J.Gondzio@ed.ac.uk

Timetable: 12 hours (6 per week or 12 in the 1st week). May 14-27, 2018, Torre Archimede,

Course requirements: some knowledge of convexity theory is assumed. Students are supposed to have attended some introductory course on optimization.

Examination and grading: grading will be based on homework assignments (several small exercises to solve in an open-book style).

SSD: MAT/08 Numerical Analysis

Aim: To familiarize students with powerful interior point techniques for optimization.

Course contents:
This course will consider the theory and some practical aspects of interior point methods for very large scale optimization. It will consider linear, quadratic, nonlinear, second-order cone, and semidefinite programming. A proof of polynomial complexity of the primal-dual method for linear programming will be given and several practical aspects of efficient implementation of the method will be discussed.

Bibliography
Approximation and complexity

Prof. Leszek Plaskota¹

¹Institute of Applied Mathematics and Mechanics, University of Warsaw, email: leszekp@mimuw.edu.pl

Timetable: COURSE CANCELLED

Course requirements: basic knowledge of numerical analysis (polynomial interpolation, quadratures), and functional analysis (continuous linear operators, Banach spaces, Hahn-Banach theorem)

Examination and grading: based on student’s activity and homeworks given during the course

SSD: MAT/08

Aim: The aim is to present rudiments of information-based complexity (IBC), which deals with computational complexity of problems for which available information is partial, noisy, and priced. Selected problems from approximation theory that are important for IBC will be discussed as well.

Course contents:

A. Topics in approximation theory
   1. Optimal approximation by polynomials
   2. Lethargy theorem
   3. Theorems of Jackson and Bernstein

B. Information-based complexity
   1. Optimality of linear algorithms
   2. Adaption versus non-adaption
   3. Worst case versus asymptotic setting
   4. Complexity of function approximation
Topics in Stochastic Analysis

Prof. Tiziano Vargiolu¹

¹Università di Padova
Dipartimento di Matematica Pura ed Applicata
Email: vargiolu@math.unipd.it

Calendario: 10 hrs. First lecture on October 10, 2017, 14:30 (dates already fixed, see the calendar), Torre Archimede, Room 2BC/30 (lectures on Oct. 10, 17, 24) and Room 2AB/45 (lectures on Oct. 12, 19).

Prerequisiti: A previous knowledge of the basics of continuous time stochastic analysis with standard Brownian motion, i.e. stochastic integrals, Itô formula and stochastic differential equations, as given for example in the master course ”Analisi Stocastica”.

Tipologia di esame: Seminar

SSD: MAT/06

Programma: The program will be fixed with the audience according to its interests. Some examples could be:

- continuous time stochastic control;
- Levy processes;
- numerical methods;
- stochastic control.
Courses of the “Mathematics” area
On Lie ring methods in group theory

Prof. Cristina Acciarri¹

¹University of Brasilia, Department of Mathematics
e-mail: c.acciarri@mat.unb.br

Timetable: 16 hours. First lecture on Nov. 7, 2017, 14:30 (dates already fixed, see calendar), Torre Archimede, Room 2BC/30.

Course requirements: Basic knowledge of linear algebra and group theory.

Examination and grading: Seminar

SSD: MAT/02

Aim: The course provides an introduction to a Lie ring method of studying groups, which is based on the so-called associated Lie rings, and aims at illustrating how a Lie theoretic result of E. Zelmanov enables one to treat problems in group theory.

Course contents:
• Lie ring and Lie algebras: definitions and basic properties. Results on Lie ring analogous to theorems about groups (nilpotency, solubility, etc).
• Constructing a Lie ring from a group. Some special cases of strongly central series: the lower central series, the lower central p-series and the p-dimension central series. Relations between the properties of the group and the properties of the associated Lie ring.
• The restricted Burnside problem: an historical overview. From the P. Hall and G. Higman work to the results of E. Zelmanov. The restricted Burnside problem for groups of prime exponent. The Lie ring of a group of prime exponent: the Magnus-Sanov theorem and the Kostrikin theorem.
• Lie rings and automorphisms of finite order. The importance of extending the ground ring and decomposing the Lie ring into a sum of analogues of eigenspaces. Bounding the exponent of a finite group with automorphisms: a result of E. Khukhro and P. Shumyatsky. A combination of the Lie-theoretic techniques developed by E. Zelmanov in his positive solution to the restricted Burnside problem and the theory of Lie algebras satisfying polynomial identities (PI theory).

References


Variational Mean Field Games

Dott.ssa Annalisa Cesaroni\textsuperscript{1}, Dott. Marco A. Cirant\textsuperscript{2}

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Dipartimento di Matematica
Email: acesar@math.unipd.it
\textsuperscript{2}Universit\`a degli Studi di Padova
Dipartimento di Matematica
Email: cirant@math.unipd.it

\textbf{Timetable:} 16 hrs. 4 weeks in the period March-April 2018. Torre Archimede, Room 2BC/30.

\textbf{Course requirements:} Basic knowledge of elliptic and parabolic PDEs, stochastic processes and Sobolev spaces.

\textbf{Examination and grading:} the exam will be oral and tailored on the basis of the students’ attitude

\textbf{SSD: MAT/05}

\textbf{Aim:} To provide an introduction to some PDE methods in Mean Field Games, in particular to the variational approach based on convex optimization methods.

\textbf{Course contents:}

- Recall of basic stochastic calculus and partial differential equations associated to diffusion processes The Hamilton-Jacobi-Bellman equation and the Fokker-Planck equation.
- Recall of basic notions about convex optimization problems and duality, min-max theorems.
- Heuristic derivation of the Mean Field Games system and connection with optimization problems.
- The energy associated to potential Mean Field Games. Basic results and a-priori estimates.
- Construction of solutions to the MFG system as minimisers of appropriate variational problems.
- Uniqueness type results and counterexamples to uniqueness for appropriate potentials.
- Long time behaviour of MFG system and convergence to steady state solutions.
Mean-field control and new types of games

Prof. Massimo Fornasier

1Technische Universität München, Fakultät für Mathematik, München, Germany
Email: massimo.fornasierematma.tum.de


Course requirements:

Examination and grading:

SSD: MAT/05, MAT/06, MAT/08

Aim:

Course contents:
This series of informal lectures presents novel results on modeling, control, and game playing of multi-agent dynamics. We focus in particular on three topics:

- sparse control, i.e., steering a large group of interacting agents by influence parsimoniously only few of them;
- mean-field control, i.e., the control of the mean-field equations describing the evolution of the probability distribution of a large population of agents;
- mean-field differential and evolution games.

The lecture series starts with basic results and it requires knowledge of relatively standard functional analysis (mainly basics of metric and Banach spaces and Bochner integration).

The analysis content of the lecture series follows:

- Existence and uniqueness solutions of the Caratheodory differential equations
- Classical examples of multiagent dynamics
- Wasserstein distances and optimal transport
- Existence and uniqueness of mean-field equations
- Introduction to optimal control and first order optimality conditions
- Introduction to Gamma-convergence
- Sparse stabilization and optimal control of multiagent dynamics
- Smooth relaxation of sparse mean-field optimal control
- Sparse mean-field optimal control
- Mean-field Pontryagin maximum principle
- Mean-field differential games
- Mean-field evolution games
Geometric Control Theory And Self-Propulsion In Fluids

Dott. Laetitia Giraldi\textsuperscript{1}, Dott. Marta Zoppello\textsuperscript{2}

\textsuperscript{1} INRIA Sophia Antipolis Meditterane Team/equipe McTAO, Nice
Email: laetitia.giraldi@inria.fr
\textsuperscript{2} Dipartimento di Matematica, Università di Padova
Email: mzoppell@math.unipd.it

\textbf{Timetable:} 15 hours. First lecture on Monday Nov. 6, 2017, 11:00 (dates already fixed, see the calendar), Torre Archimede, Room 2BC/30.
First part (12 hours) by Marta Zoppello, second part (4 hours) by Laetitia Giraldi

\textbf{Examination and grading:} Oral exam tailored on the students who will attend the course.

\textbf{SSD:} MAT/07

\textbf{Course contents:}
In the period from the 6 to 19 of November, Marta Zoppello will give the first 12 hours during which she will enter in the mathematical details that are fundamental to end up with the results that Laetitia will present in the second part.
In after Laetitia Giraldi Junior Researcher at INRIA Sophia Antipolis Meditterane Team/equipe McTAO, will begin the last two lessons of the course (4 hours). She will present the latest ongoing results in the field of the control of magneto-micro swimmers and the most standard geometric tools used to have controllability results.
More precisely the course will begin with some basic notions of differential geometry and fiber bundles. These concepts are fundamental to interpret the dynamic ordinary differential equations as a control system in which some of the coordinates are prescribed. The course will contain the main theorems and definitions of geometric control theory that will be exploited in the final examples. Then we will proceed with an introduction to the Navier Stokes equations and the definition of Reynolds number (Re). We will analyze in detail the case in which the Reynolds number is very high, so that the fluid can be seen as an ideal and irrotational one, and the opposite situation in which the Reynolds number is very small and the fluid can be approximated as a viscous one. Finally we are able to introduce the example of a micro-swimmer, mention some optimization techniques and reconnect to the main examples presented at the beginning
Revisiting the de Rham-Witt complex

Prof. Luc Illusie¹

¹ Université Paris-Sud
91405 Orsay Cedex - France
Email: Luc.Illusie@math.u-psud.fr

Timetable: 12 hours. First lecture on November 10, 2017, 14:30 (dates already fixed, see the calendar), Torre Archimede, Room 2BC/30.

Course requirements: Basic knowledge of commutative algebra, algebraic geometry, cohomology theory.

Examination and grading: the exam will be oral and tailored on the basis of the students attitude

SSD: MAT/03

Aim: To provide an introduction to the de Rham-Witt complex and its applications.

Course contents: The de Rham-Witt complex was constructed by Spencer Bloch in the mid 1970’s as a tool to analyze the crystalline cohomology of proper smooth schemes over a perfect field of characteristic $p \neq 0$, with its action of Frobenius, and describe its relations with other types of cohomology, like Hodge cohomology or Serre’s Witt vector cohomology. Since then many developments have occurred. After recalling the history of the subject, we will explain the main construction and in the case of a polynomial algebra give its simple description by the so-called complex of integral forms. We will then describe the local structure of the de Rham-Witt complex for smooth schemes over a perfect field and its application to the calculation of crystalline cohomology. In the proper smooth case, we will discuss the slope spectral sequence and the main finiteness properties of the cohomology of the de Rham-Witt complex in terms of coherent complexes over the Raynaud ring. We will mention a few complements (logarithmic Hodge-Witt sheaves, Hyodo-Kato log de Rham-Witt complex, Langer-Zink relative variants), and make a tentative list of open problems.
Partial Differential Equations of Mathematical Physics

Prof. Alexey Karapetyants

Southern Federal University and Don State Technical University, Russia
Email: karapetyants@gmail.com

Timetable: 10 hours. First lecture on February 13, 2018, 09:00 (dates already fixed, see the calendar), Torre Archimede, Room 2BC/30

Course requirements: Knowledge of basic university facts on functions of real and complex variables, differential equations, algebra and geometry. Everything is up to the level of understanding basic university courses which include these subjects.

Examination and grading: During the course I will ask some questions for homework activity. Those who will complete these homework questions will get score up to 50% of the total. The final test (quiz) will be given to the students, and on the base of this test a student may have also up to 50% of the total score. Those students who will consider their score lower than they’ve expected will be provided with an opportunity to defend their answers with no restrictions on time after the last lecture.

SSD: MAT/05

Aim: The course discusses the application of mathematics to problems in physics and development of the mathematical methods suitable for such applications and for the formulation of physical theories and effects. It is aimed to provide the students with a theoretical and practical knowledge of the studying and solving problems inspired by physics or thought experiments within a mathematically rigorous framework.

Course contents:
The course briefly covers elliptic, parabolic and hyperbolic equations in a various setting. It provides with classical formulae for solutions and physical meaning of these formulas. It also treats the concept of correctness, generalized solutions and regularizations. It covers to some extent notions and useful facts of Fourier analysis, orthogonality and special functions, including Bessel functions, potential theory, harmonic functions and Lyapunov surfaces.
Compact complex surfaces

Prof. Remke Kloosterman

1 Department of Mathematics, University of Padova
Email: klooster@math.unipd.it

Timetable: 20 hours. March-April 2018, Torre Archimede,

Course requirements: Basic notions from complex analysis and algebraic topology. Preferably also some basic knowledge of algebraic geometry.

Examination and grading: Oral exam, tailored to the research interests of the students.

SSD: MAT/02, MAT/03, MAT/05, MAT/07

Aim: Describing the classification of compact complex surfaces (both algebraic and non-algebraic).

Course contents:

In a course on Riemann surface one usually shows that every compact complex curve is algebraic (i.e., a projective curve). This statement is false in higher dimension. In the first part of the course we discuss the classification of compact complex surfaces which are not projective. Compact complex curves are classified by their genus, in the second part of the course we discuss a similar classification (due to Enriques) of compact complex algebraic surfaces. In the two final lectures we discuss a few examples of compact complex surfaces with a particular rich geometry such as Del Pezzo surfaces, K3 surfaces, Enriques surfaces and elliptic surfaces.
Contramodules and their applications in commutative algebra

Prof. Leonid Positselski

1Russian Academy of Sciences, Mosca
Email: posic@mccme.ru

Timetable: 16 hrs. First lecture on January 10, 2018 (dates already fixed, see the calendar), Torre Archimede, Room 2BC/30.

Course requirements:

Examination and grading: knowledge of the basic concepts of homological algebra, such as the functors Ext and Tor and the definition of the derived category of modules, will be largely presumed.

SSD: MAT/02

Aim:

Course contents: Contramodules are module-like algebraic objects endowed with infinite summation operations, understood algebraically as infinitary linear operations subject to natural axioms. Contramodule categories appear as abelian right orthogonal subcategories in the categories of modules. Striking applications of contramodules to problems of commutative algebra, such as module structure of flat finitely presented commutative algebras over commutative rings, a description of strongly flat and weakly cotorsion modules, the structure of flat modules over Noetherian commutative rings with countable spectrum etc., have been recently discovered. This course will start with a discussion of infinite summation operations in modules over commutative rings and end with the proofs of the above-mentioned results.
Systems of conservation laws
in one space variable

Dott.ssa Laura Spinolo

1IMATI-CNR, Pavia
Email: laura.spinolo@cnr.imati.it

Timetable: 16 hrs., on April 2018. Torre Archimede.

Course requirements: very basic notions of PDE theory (definition of distributional solution, definition of Sobolev space).

Examination and grading: seminar

SSD: MAT/05 - Mathematical Analysis

Aim: the course aims at providing an introduction to the analysis of systems of conservation laws in one space variable. Although due to time constraints I will mostly focus on the scalar case, I will introduce techniques that have been successfully applied to the case of systems.

Course contents: I will discuss existence and uniqueness results for systems of conservation laws in one space variable. Systems of conservation laws are partial differential equations with several applications coming from both physics and engineering, in particular from fluid dynamics and traffic modeling. Despite recent progress, the mathematical understanding of these equations is still largely incomplete and many fundamental problems are presently open. For instance, no well-posedness theory is presently available for systems of conservation laws in several space variables. The tentative schedule is as follows.

• Classical solutions, the theory of characteristics.
• Distributional solutions, Rankine-Hugoniot conditions.
• Admissibility criteria for distributional solutions. The solution of the Riemman problem.
• Existence of global in time, admissible distributional solutions. The wave-front tracking algorithm.
• Initial-boundary value problems.
Linear differential equations and Stokes structure

Prof. Jean-Baptiste Teyssier¹

¹KU Leuven
Email: jeanbaptiste.teyssier@kuleuven.be

Timetable: 10 hrs. First lecture on April 4, 2017, 10:30 (dates already fixed, see the calendar), Torre Archimede, Room 2BC/30.

Course requirements:

Examination and grading:

SSD: MAT/03, MAT/05

Aim:
The goal of this course is to explain how Stokes filtered local systems in dimension one classify local analytic differential equations of one variable. We will also give an overview of what is known in the higher dimensional case

Course contents:
The formal study of linear differential equations is now well understood by means of Kedlaya-Mochizuki theorem. On the other hand, the analytic study of linear differential equations is an active research topic involving completely different techniques and structures.
The Master Degree (Laurea Magistrale) in Mathematics of this Department offers many courses on a wide range of topics, in Italian or in English. The PhD students are encouraged to follow the parts of such courses they think are useful to complete their basic knowledge in Mathematics. In some cases this activity can receive credits from the Doctoral school, upon recommendation of the supervisor of the student. Since the courses at the Master level are usually less intense than those devoted to graduate students, the number of hours given as credits by our Doctorate will be less than the total duration of the course. Some examples of courses that receive such credits, unless the student already has the material in his background, are the following.
Topology 2

Prof. Andrea D’Agnolo
Università di Padova, Dipartimento di Matematica
Email: dagnolo@math.unipd.it

Period: 1st semester

Contents and other information:

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Representation Theory of Groups

Prof. Giovanna Carnovale
Università di Padova, Dipartimento di Matematica
Email: carnoval@math.unipd.it

Period: 2nd semester

Contents and other information:

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Homology and Cohomology

Prof. Bruno Chiarellotto
Università di Padova, Dipartimento di Matematica
Email: chiarbru@math.unipd.it

Period: 2nd semester

Contents and other information:
Other courses suggested to the students

The students are encouraged to follow also courses outside Padova if they are useful for their training to research, in accordance with their supervisor. Parts of such course can be counted in fulfilment of their duties, provided the student passes an exam. The number of hours recognised as credits will be decided by the Coordinator after hearing the supervisor. Some examples of courses that receive such credits are the following.
Advanced topics in stochastic processes

Proff. J. Grilli, A. Maritan and S. Suweis

Possible calendar:

First Part
Tuesday 7, 14 Nov. from 14.30 to 16:30 - Thursday 9, 16 Nov. from 14.30 to 16:30

Second Part
Tuesday 21, 28 Nov. from 10.30 to 12.15 - Thursday 23, 30 Nov. from 10.30 to 12.15

Third Part
Tuesday 5, 12 Dec. from 10.30 to 12.15 - Thursday 7, 14 Dec. from 10.30 to 12.15

For other information: please visit http://www.dfa.unipd.it/index.php?id=1680

Course contents:

First part: Amos Maritan
1. Stochastic differential equations and Ito calculus
2. Power spectrum and amplification of stochastic noise
3. Multivariate Ornstein-Uhlenbeck process
4. Feynman Kac-formula
5. Kramers-Moyal expansion, van Kampen size expansion

Second Part: Jacopo Grilli
1. Introduction to Random Matrix and its application
2. Replica Trick for Wigner matrix. Replica caveats and super symmetric method.
5. Doe, resolvent and techniques for non-hermitian matrices (with quaternion algebra)

Third Part: Samir Suweis.
1. Introduction: complexity-stability paradox. Lotka-Volterra models and demographic stochasticity
3. Ecological networks and a generalization of the Voter Model
4. Application of Van Kampen expansion size in Ecology

Bibliography
Summer School on Mathematics in Imaging Science,

May 28 - June 1, 2018, University of Bologna;
person in charge of the final exam: Prof. Serena Morigi serena.morigi@unibo.it
website of the School: https://site.unibo.it/summer-school-siam-is18/en/school

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Summer Courses in Perugia and Cortona

S.M.I.-Scuola Matematica Interuniversitaria
website: http://germanio.math.unifi.it/it

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Courses in collaboration with the Doctoral School on “Information Engineering”

The courses with * contain material that should be already known to a graduate student in Mathematics. Therefore the number of hours given as credits by our Doctorate will be less than the total duration of the course. The exact number of credits will be determined by the Coordinator after hearing the student and, if necessary, his/her supervisor.
Model Predictive Control

Prof. Ruggero Carli et. al

Timetable: Course of 20 hours (2 two-hours lectures per week). Tentative schedule: Class meets every Tuesday from 10:30 to 12:00 and Thursday from 10:30 to 12:00. First lecture on Tuesday, 30th January, 2018. Room DEI/G, 3-rd floor, Dept. of Information Engineering, via Gradenigo Building.

Other Instructors: Dr. Mattia Bruschetta, Dr. Simone Del Favero.

Course requirements: Basic Calculus and Linear Algebra.

Examination and grading: Homework and take home exam.

Aim: The course will provide the basic knowledge of Model Predictive Control (MPC). The course will also present some practical examples related to Automotive and Bioengineering applications.

Topics

1. Introductory Material: State Space Models; Prediction and Current State Estimation (Kalman Filter); Linear Quadratic Problem, Dynamic Programming Solution

2. Getting started with Model Predictive Control: The Infinite Horizon LQ Problem, Convergence of the Linear Quadratic Regulator


4. Robust MPC and explicit MPC: Types of Uncertainty, Nominal robustness, tube-based robust MPC, Explicit Control Laws for Constrained Linear Systems


6. Automotive applications: Motion Cueing Algorithms, Virtual Rider, Autonomous Driver.

7. Bioengineering application, the Artificial Pancreas: The Blood Glucose Regulation Problem, possible MPC Approaches (modular MPC, zone MPC, non-linear MPC), Clinical Testing.

References:


Other material and research papers will be available online for download.
Applied Linear Algebra*

Prof. Fernando De Terán¹, Prof. Michael Karow²

¹Universidad Carlos III de Madrid, Spain
Email: fteran@math.uc3m.es

²Technische Universität Berlin, Germany
Email: karow@math.tu-berlin.de

Timetable: 16 hours.
First part (De Terán): Class meets on Tuesday and Thursday, from 10.30 to 12.30. First Lecture on March 13th, 2018
Second part (Karow): Class meets on Tuesday and Thursday, from 10.30 to 12.30. First Lecture on March 27th, 2018

Course requirements: A good working knowledge of basic notions of linear algebra as for example in [1]. Some proficiency in MATLAB.

Examination and grading: Grading is based on homeworks or a written examination or both.

Aim: We study concepts and techniques of linear algebra that are important for applications with special emphasis on the topics: (a) solution of systems of linear equations (with particular attention to the analysis of the backward error and computational cost of the basic algorithms) and (b) matrix equations and inequalities. A wide range of exercises and problems will be an essential part of the course and constitute homework required to the student.

Course contents:

1. Review of some basic concepts of linear algebra and matrix theory
2. Gaussian elimination.
3. LU factorization.
4. Positive (semi) definite matrices and Cholesky factorization.
5. Matrix exponential
7. Applications to Control Theory.

References:

[1] Gilbert Strang’s linear algebra lectures, from M.I.T. on You Tube
[3] Notes from the instructors
Bayesian Machine Learning

Prof. Giorgio Maria Di Nunzio¹

¹ Dept. of Information Engineering, University of Padova
Email: dinunzio@dei.unipd.it


Examination and grading: Homework assignments and final project.

Aim: The course will introduce fundamental topics in Bayesian reasoning and how they apply to machine learning problems. In this course, we will present pros and cons of Bayesian approaches and we will develop a graphical tool to analyse the assumptions of these approaches in classical machine learning problems such as classification and regression.

Course contents:

- Introduction of classical machine learning problems.
  - Mathematical framework
  - Supervised and unsupervised learning

- Bayesian decision theory:
  - Two-category classification
  - Minimum-error-rate classification
  - Bayes decision theory
  - Decision surfaces
  - Regression

- Estimation:
  - Maximum Likelihood Estimation
  - Expectation Maximization
  - Maximum A Posteriori
  - Bayesian approach

- Graphical models:
  - Bayesian networks
  - Two-dimensional visualization

- Evaluation:
  - Measures of accuracy
References:

Statistical methods

Prof. Lorenzo Finesso¹

¹Istituto di Elettronica e di Ingegneria dell'Informazione e delle Telecomunicazioni, IEIIT-CNR, Padova
Email: lorenzo.finesso@unipd.it


Course requirements: familiarity with basics linear algebra.

Examination and grading: homework and take-home exam.

Aim: The course will present a small selection of statistical techniques which are widespread in applications. The unifying power of the information theoretic point of view will be stressed.

Course contents:

• Background material. The noiseless source coding theorem will be quickly reviewed in order to introduce the basic notions of entropy and I-divergence

• Divergence minimization problems. Three I-divergence minimization problems will be posed and, via examples, they will be connected with basic methods of statistical inference: ML (maximum likelihood), ME (maximum entropy), and EM (expectation-maximization).

• Multivariate analysis methods. The three standard multivariate methods, PCA (Principal component analysis), Factor Analysis, and CCA (Canonical Correlations analysis) will be reviewed and their connection with divergence minimization discussed. Applications of PCA to least squares (PCR principal component regression, PLS Partial least squares). Approximate matrix factorization and PCA, with a brief detour on the approximate Non-negative Matrix Factorization (NMF) problem. The necessary linear algebra will be reviewed.

• EM methods. The Expectation-Maximization method will be introduced as an algorithm for the computation of the Maximum Likelihood (ML) estimator with partial observations (incomplete data) and interpreted as an alternating divergence minimization algorithm (à la Csiszár Tusnády).


References: A set of lecture notes and a complete list of references will be posted on the web site of the course.
Computational Inverse Problems

Prof. Fabio Marcuzzi

1 University of Padova
Department of Mathematics
Email: marcuzzi@math.unipd.it

Timetable: Course of 20 hours (2 two-hours lectures per week): Classes on Monday and Wednesday, 10:30 - 12:30. First lecture on Monday February 26th, 2018. Room DEI/G, 3rd floor, Dept. of Information Engineering, via Gradenigo Building.

Course requirements: basic notions of linear algebra and, possibly, numerical linear algebra. The examples and homework will be in Python (the transition from Matlab to Python is effortless).

Examination and grading: Homework assignments and final test.

SSD: MAT/08

Aim: We study numerical methods that are of fundamental importance in computational inverse problems. Real application examples will be given for distributed parameter systems in continuum mechanics. Computer implementation performance issues will be considered also.

Course contents:

• definition of inverse problems, basic examples and numerical difficulties.
• numerical methods for QR and SVD and their application to the squareroot implementation in PCA, least-squares, model reduction and Kalman filtering; recursive least-squares;
• regularization methods;
• numerical algorithms for nonlinear parameter estimation: Gauss-Newton, Levenberg-Marquardt;
• examples with distributed parameter systems;
• HPC implementations.

References:

Applied Functional Analysis and Machine Learning*

Prof. Gianluigi Pillonetto¹

¹ Dept. of Information Engineering, University of Padova
Email: giapi@dei.unipd.it

Timetable: Course of 28 hours (2 two-hours lectures per week): Classes on Tuesday 10:30 - 12:30 and Wednesday, 8:30 - 10:30. First lecture on Wednesday November 28th, 2017. Sala Riunioni 318 DEI/G 3-rd floor, via Gradenigo 6).

Course requirements: The classical theory of functions of real variable: limits and continuity, differentiation and Riemann integration, infinite series and uniform convergence. The arithmetic of complex numbers and the basic properties of the complex exponential function. Some elementary set theory. A bit of linear algebra.

Examination and grading: Homework assignments and final test. Students wishing to take the exam for this course, are kindly requested to contact the Coordinator of the PhD program in Mathematical Sciences.

Aim: The course is intended to give a survey of the basic aspects of functional analysis, machine learning, regularization theory and inverse problems.

Course contents:


References:


Other material and research papers will be available online for download.
Calendar
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### Calendario della Giornata

#### Maggio 2018

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**Nota:** Il calendario si riferisce ai giorni lavorativi e alle rispettive ore di attività.
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