Doctoral Course in Mathematical Sciences
Department of Mathematics
University of Padova

Doctoral Course in Mathematical Sciences
Catalogue of the courses 2019

Updated January 22, 2019
INTRODUCTION

This Catalogue contains the list of courses offered to the Graduate Students in Mathematical Sciences for the year 2018-19.

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 Doctoral Program" 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 2019 or later, and as soon as possible for courses that take place until December 2018.

In order to register, follow the procedure described in the preceding paragraph. Possible cancellation to courses must also be notified.
Courses of the Doctoral Program

1. Prof. Bruno Chiarellotto, Prof. Adrian Iovita
   The Fundamental Group DP-1

2. Prof. Marco di Summa
   Convex optimization and convexification techniques DP-2

3. Prof. Francesco Fassó
   Lie Groups and Symmetry DP-3

4. Prof. Massimo Fornasier
   Foundations of Data Analysis DP-4

5. Prof. Davide Vittone
   Introduction to the theory of optimal Transportation DP-5

Courses of the “Computational Mathematics” area

1. Prof. Nicholas Gabriel Andjiga
   Introduction to Social Choice Theory MC-1

2. Dott. Cristina Campi, Dott. Davide Poggiali
   An introduction to numerical approaches to reconstruction in medical imaging MC-2

3. Prof. Giorgio Ferrari, Prof. Tiziano Vargiolu
   Optimal Stopping, Singular and Impulsive Stochastic Control and Applications in Economics and Finance MC-3

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

5. Prof. Michael A. Slawinski
   Mathematical Modeling: Forward and Inverse Problems in Seismology MC-6

Courses of the “Mathematics” area

1. Prof. Fabio Ancona, Prof. Andrea Marson
   Introduction to Hyperbolic Conservation Laws M-1

2. Prof. Italo Capuzzo-Dolcetta
   The Maximum Principle for Elliptic Equations M-2

3. Prof. Pierre Cardaliaguet
   Analysis on the space of measures M-3

4. Prof. Mama Foupouagnigni
   On Differential Equations for Orthogonal Polynomials M-4
5. Prof. Jean-Paul Gauthier  
Motion Planning in the Subriemannian framework  

6. Prof. Shingo Kamimoto  
Gevrey asymptotics  

7. Prof. Benjamin Klopsch  
Representation growth and zeta functions  

8. Prof. Bao Viet Le Hung  
Elliptic Curves and Modularity  

9. Prof. Franco Rampazzo  
Mathematical Theory of Control  

Courses offered within the Masters’s Degree in Mathematics  

1. Offered Courses  

Other courses suggested to the students  

1. Other suggested Courses  

2. Soft Skills Courses  

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

1. Prof. Fernando De Terán, Prof. Michael Karow  
Applied Linear Algebra  

2. Prof. Subhrakanti Dey  
Distributed Optimization and Applications  

3. Prof. Giorgio Maria Di Nunzio  
Bayesian Machine Learning  

4. Prof. Deniz Gunduz  
Introduction to Information Theory  

5. Prof. Lorenzo Finesso  
Statistical Methods
6. Prof. Fabio Marcuzzi  
   Computational Inverse Problems  
   DEI-6

7. Prof. Gianluigi Pillonetto  
   Applied Functional Analysis and Machine Learning  
   DEI-7

8. Prof. Domenico Salvagnin  
   Heuristics for Mathematical Optimization  
   DEI-8

9. Prof. Daniel Zelazo  
   Analysis and Control of Multi-Agent Systems  
   DEI-9
Courses of the Doctoral Program
The fundamental group

Bruno Chiarellotto¹, Adrian Iovita²

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Email: chiarbru@math.unipd.it
²Department of Mathematics, University of Padova
Email: iovita@math.unipd.it

Timetable: 24 hrs., 2019, Torre Archimede, Room 2BC/30.

Course requirements: the student is supposed to know: basic topology and basic geometry.

Examination and grading:

SSD: MAT/02 MAT/03

Aim:

Course contents:
We will try to show how the basic construction of the topological fundamental group can be generalized in other frameworks and in higher homotopy invariants. Among the aim of the class it will be to show how the Classical Galois Group of a field \( k \) can be linked to the generalization of the fundamental group calculated on the arithmetic/algebraic space linked to the space (scheme) associated to the field \( k \). Moreover an algebraic variety (i.e. zeroes of a polynomial in several variables) over \( \mathbb{C} \) can be seen as a topological space with its own topological fundamental group. What about the algebraic fundamental group”, which involves only ”geometric coverings” (i.e. given by polynomials)? During the class we will try to explain some trends of recent researches.

1. Classical definitions of the first homotopy group and higher homotopy theory. Singular Homology.
2. Representations of the fundamental group: local systems. Fibration and fundamental group. Homology relations.
4. The covering spaces of a scheme. Tate topology. Interpretation of the fundamental group. Link with the classical definition.

During the class we will follow some texts (Grütz ”Algebraic Geometry I: schemes and exercises”. Rotman ”Introduction to algebraic topology”) and some notes from the teachers.
Convex optimization and convexification techniques

Marco Di Summa

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

Timetable: 24 hrs. First lectur on March 4, 2019, 11:00 (dates already fixed, see calendar), Torre Archimede, Room 2BC/30.

Course requirements:

Examination and grading:

SSD: MAT/09

Aim: We will try to achieve two partly contrasting targets: on the one hand, students who have never attended any course in Operations Research will learn some fundamental notions in this area, in particular in the field of convex optimization and its application to discrete optimization problems; on the other hand, students with some knowledge in Operations Research will see a variety of results in convex optimization that are usually not covered in master programs, as well as alternative algorithms for some fundamental optimization problems and the interplay between continuous and discrete optimization.

Course contents:

1. Representation of convex sets, support functions, gauge functions, separation theorems.
4. The special case of linear programming and polyhedra. Algorithms not based on the simplex method.
Lie Groups and Symmetry

Francesco Fassó

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

Timetable: 24 hrs. First lecture October 9, 2019, 11:00 (dates already fixed, see calendar), Torre Archimede, Room 2BC/30.

Course requirements: (very) basic knowledge in differential geometry. The course is addressed to all students.

Examination and grading: oral examination on the topics covered during the course

SSD: MAT/

Aim: The course aims at providing an introduction to the theory of Lie groups and their actions, which is a topic of broad interest but almost completely absent from the courses of our Laurea Magistrale. After covering the fundamentals of the subject, the course will provide some examples of use of Lie groups in the study of ODE with symmetry.

Course contents:
Synopsis: Lie groups and their differential—and group—structure (left and right trivializations, Lie algebra of a Lie group, exponential map, maximal tori, (co)adjoint action, structure of compact Lie groups). The classical matrix groups and their properties. Differentiable actions of Lie groups on manifolds, quotient spaces (for proper actions), invariant vector fields. Reduction of invariant vector fields. Applications to ODEs with symmetry (reduction and reconstruction; integrability).

References
3. T. Brcker and T. tom Dieck, Representations of compact Lie groups. (Springer 1985)
Foundations of Data Analysis

Massimo Fornasier¹

¹Technische Universität München, Fakultät für Mathematik, München, Germany
Email: massimo.fornasier@matma.tum.de

Timetable: 24 hrs. First lecture on March 11, 2019, 14:30 (dates already fixed, see calendar), Torre Archimede, Room 2BC/30.

Course requirements:

Examination and grading:

SSD: MAT/02-03, MAT/06

Aim:

Course contents:

The course starts with re-introducing main notations and notions of linear algebra, for then introducing the singular value decomposition and its main mathematical properties and interpretations.

We will indulge on several applications of the singular value decomposition relevant for data analysis such as the Principal Component Analysis, Low-rank Approximation and Compression, Document Ranking, and Least Squares problems.

We show how randomization plays a significant role in breaking the curse of dimensionality for the computation of the singular value decomposition of humongous matrices.

In order to address more formally probabilistic arguments and concentration of measure phenomena, we focus on basic tools of probability theory, so to be able to prove the two fundamental Hoeffdings and Bernstein inequalities.

We show then one application of these inequalities by proving the celebrated Johnson-Lindenstrauss lemma, of the randomized quasi-isometrical mapping of large and high-dimensional data sets to lower dimensions.

While linear algebra and probability are certainly fundamental tools for big data analysis, the picture would not be complete without an introduction on convex analysis and convex optimization methods, to which we will dedicate a relevant introduction. As an application of the fusion of linear algebra, probability, and optimization, we present the theory of compressed sensing and sparse recovery, i.e., the nonadaptive randomized acquisition of (sparsely representable) high-dimensional data and their optimal recovery methods.
Introduction to the theory of optimal Transportation

Davide Vittone¹

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


Course requirements: Basic notions of measure theory

Examination and grading:

SSD: MAT/05

Aim: The course aims at introducing the fundamental ideas and results in the theory of Optimal Transportation as well as some applications in different areas of Mathematics.

Course contents:

Part 1: general theory
- Monge and Kantorovich formulation
- Duality theorems
- Existence of optimal transport plans
- Existence of optimal transport maps: Brenier theorem in the case p=2

Part 2: applications, to be chosen among
- Geometric inequalities
- Ramified optimal transport
- Monge-Ampere equation
- Introduction to Wasserstein spaces
- A metric approach to Ricci curvature.

References
1. C. Villani, Topics in Optimal Transportation, Springer
3. F. Santambrogio, Optimal Transport for Applied Mathematicians, Birkhauser
Courses of the “Computational Mathematics” area
Introduction to Social Choice Theory

Prof. Nicholas Gabriel Andjiga¹

¹ Université Yaoundé I
Email: andjiga2002@yahoo.fr

Timetable: 12 hrs. First lecture on January 23, 2018, 16:00 (dates already fixed, see calendar). Torre Archimede, Room 2BC/30.

Course requirements:

Examination and grading:

SSD: MAT04, MAT06

Aim:

Course contents: Social choice theory is the mathematical study of mechanisms which associate a collective decision to individual choices. The main example is the situation of votes. We will give an overview of what is done in this domain and what are the open problems.
An introduction to numerical approaches to reconstruction in medical imaging

Cristina Campi¹, Davide Poggiali²

¹Dipartimento di Medicina, University of Padova
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²Department of Mathematics, University of Padova
Email: poggiali.davide@gmail.com

Timetable: 16 hrs. First lecture on November 7, 2018, 09:00 (dates already fixed, see calendar).
Torre Archimede, Room 2BC/30

Course requirements: introductory course(s) on numerical analysis and basic programming skills*. Familiarity with probability and statistics can be helpful but is not required.

Examination and grading: based on project assignment.

SSD: MAT/08 Numerical Analysis

Aim: The course intends to introduce reconstruction problems for tomographic and biomagnetic data. In medical imaging these problems need to be solved in order to transform raw data into human-readable images. From a mathematical view point, these problems are formulated in the inverse problems framework and this course aims to present computational approaches for their solution and the related numerical issues.

Course contents:
The course aims at introducing the student to:

- Part I: Electroencephalography (EEG) and Magnetoencephalography (MEG) (overview);
  Regularization methods
- Part II: Lab experience on MEG data.
- Part III: X-ray Computed Tomography (CT), Positron Emission Tomography (PET) (overview)
  and Single Photon Emission Tomography (SPECT) (overview). Radon transform, formulas for
  the inversion of the Radon transform (as back projection and filtered back projection).
  Iterative methods.
- Part IV: Lab experience on Radon transform.

References:


Optimal Stopping, Singular and Impulsive Stochastic Control and Applications in Economics and Finance

Giorgio Ferrari\(^1\), Tiziano Vargiolu\(^2\)

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Email: giorgio.ferrari@uni-bielefeld.de
\(^2\)Dipartimento di Matematica, Università di Padova
Email: vargiolu@math.unipd.it

First lecture of Part 1 on October 24, 2018, 14:30 (dates already fixed, see calendar), Torre Archimede, Room 2BC/30.

**Course requirements:** Knowledge of stochastic analysis and ODE/PDE theory.

**Examination and grading:**

**SSD:** SEC-06

**Introduction:** In this course we will introduce a class of stochastic optimization problems in continuous time that finds relevant applications in Economics and Finance, but has nonetheless independent importance for its mathematical beauty. These are optimal stopping problems, and singular and impulsive stochastic control problems. We will provide their formulation, and (some of) the methods of solutions through the study of important examples. In particular, we will concentrate on the so-called analytic approach, which brings back the stochastic problem to a suitable second-order partial differential problem, which in these particular stochastic control problems takes the form of so-called variational inequality (VI) or quasi-variational inequality (QVI), characterized by the fact that part of the problem is to find a so-called free boundary, which divides the domain into regions where different regimes are expected for the stochastic state process. These differential problems have the well-known peculiarity that their solution is typically non-smooth, in particular the second derivative is expected not to be continuous in all the domain, but has a discontinuity at the free boundary. We will also discuss the important link between optimal stopping, and singular and impulsive control problems. Finally, if time allows, we will present some examples where Volterra integral equations can be used to characterize the free boundary.

**Course contents:**

*Optimal Stopping* (ca. 8 hours):
- Formulation of optimal stopping problems.
- The Dynamic Programming Principle, the related Hamilton-Jacobi-Bellman equation (a VI), and a Verification Theorem.
- An example: optimal harvesting problem; the solution of the VI (and thus the value function) is not \(C^2\).
- Pricing problem of perpetual American options in the Black-Scholes model;
• Discussion on the pricing of finite time-horizon put options in the Black-Scholes model: early exercise premium representation; (if time allows, an integral Volterra equation for the free boundary).

**Singular Stochastic Optimal Control** (ca. 8 hours):
• Formulation of the problem through a classical example;
• The related Hamilton-Jacobi-Bellman equation (a QVI), and a Verification Theorem.
• Connection to optimal stopping and discussion on methods of solutions.

**Impulsive Stochastic Optimal Control** (ca. 8 hours):
• Formulation of the problem through a classical example.
• The related Hamilton-Jacobi-Bellman equation (a QVI), and a Verification Theorem.
• An example: optimal repeated harvesting problem; the solution of the QVI (and thus the value function) is not $C^2$;
• Connection to iterated optimal stopping.

**References**

Approximation and complexity

Prof. Leszek Plaskota¹

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

Timetable: 16 hrs. First lecture on January 10, 2019, 14:30 (dates already fixed, see calendar) Torre Archimede, Room 321 (NumLab) on 3rd floor.

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
Mathematical Modeling: Forward and Inverse Problems in Seismology

Michael A. Slawinski

\textsuperscript{1}Department of Earth Sciences, Memorial University of Newfoundland, Canada
email: mslawins@mun.ca

Timetable: 16 hrs., May-June 2019, Torre Archimede, Room 2BC/30.

Course requirements: Students are expected to have a comfortable familiarity with
- Linear algebra
- Tensor algebra and calculus
- Distributions
- Ordinary and partial differential equations
- Differential geometry
- Continuum mechanics
- Numerical issues of nonlinear processes.
However, each subject will be sufficiently reviewed based on the course needs to provide the necessary background.

Examination and grading: Brief presentation on a course-pertinent subject, Oral examination/discussion

SSD: MAT/07-08: Mathematical Modeling

Aim:
- To familiarize the students with the mathematical wealth and complexities of problems encountered in quantitative seismology.
- To examine the meaning of mathematical entities and models used as analogies for physical objects and phenomena
- To understand limitations imposed by assumptions and approximations on predictions provided by forward problems
- To recognize, and deal with, unavoidable issues of inverse problems, such as singularities and nonuniqueness

Course contents:

1. Rudiments of continuum mechanics
   - Reference and current configurations
   - Finite and infinitesimal elasticity theory
   - Balance principles
   - Constitutive equations
   - Material symmetry

2. Equations of motion in isotropic homogeneous continua
   - Wave equations
   - Solutions of wave equations (including weak solutions)
   - Surface, guided and interface waves
3. Equations of motion in anisotropic inhomogeneous continua
   - Christoffel equations
   - Hamilton equations
   - Lagrange equations
   - Legendre transformation and its singularities
   - Characteristic equations of linear and nonlinear PDEs
   - Caustics

4. Variational principles in seismology
   - Fermats principle
   - Hamiltons principle

5. Foundational issues of modeling
   - Prediction versus explanation
   - Underdetermination of theory by evidence
   - Falsicationism
Courses of the “Mathematics” area
Introduction to Hyperbolic Conservation Laws

Fabio Ancona¹, Andrea Marson²

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²Department of Mathematics, University of Padova
Email: marson@math.unipd.it

Timetable: 16hrs. March-April 2019, Torre Archimede, Room 2BC/30.

Course requirements:

Examination and grading:

SSD: MAT/05

Aim:

Course contents:
The course aims at introducing the student to:

- Fundamental features of hyperbolic evolution equations in the form of conservation laws, mostly focusing on the one space variable setting. Examples date back to Euler (1755) for describing gas dynamics, and now arise in several other fields like relativity, traffic flow, blood flow, supply-chains.

- Topics in recent research on control, networks and vanishing viscosity techniques for this class of first order Partial Differential Equations.

The course shall be of particular interest for students in Mathematica Analysis, Mathematical Physics, Numerical Analysis, especially if interested in fluid models, control problems or network structures.

Part 1: Introduction to the general theory on systems of hyperbolic conservation laws.

Part 2: To be chosen among

1. Lyapunov-type functionals for stability and control of the Cauchy problem
2. Analysis of conservation laws on networks
3. Vanishing viscosity approximation
4. Relative entropy methods for hyperbolic and hyperbolic-parabolic systems

References:

- C.M.Dafermos, Hyperbolic Conservation Laws in Continuum Physics, Fourth ed. Springer Verlag.
The Maximum Principle for Elliptic Equations

Italo Capuzzo Dolcetta

1 Dipartimento di Matematica "Guido Castelnuovo", Università di Roma La Sapienza
Email: capuzzo@mat.uniroma1.it

Timetable: 12 hrs, February-April 2019.
Lectures already set at the current date: Feb 25, 2019, 14:30 and Feb 26, 2019, 09:00, Torre Archimede, Room 2BC/30.

Course requirements: the student is supposed to know: basic topology and basic geometry.

Examination and grading:

SSD: MAT/05

Aim:

Course contents:
Some simple cases: linear and harmonic functions.
General linear uniformly elliptic operators on bounded domains. Applications to a priori estimates.
The Maximum Principle and the principal eigenvalue. The Rayleigh and the min-max formula.
Degenerate elliptic operators on bounded and domains.
Degenerate elliptic operators on unbounded domains.
The Maximum Principle and different notions of weak solutions of fully nonlinear elliptic equations.

Reference:
Some basic reference books and papers:

4. L. Caffarelli and X. Cabré, Fully Nonlinear Elliptic Equations, Colloquium Publications, Vo. 43, AMS 1995
Analysis on the space of measures

Prof. Pierre Cardaliaguet¹

¹Université Paris-Dauphine, Paris, France
Ceremade (UMR CNRS 7534)
Email: cardaliaguet@ceremade.dauphine.fr

Timetable: 12+4 hrs. April-May 2019, Room 2BC/30, Torre Archimede

Course requirements:

Examination and grading:

SSD: MAT/05 Mathematical Analysis

Aim:

Course contents:

We will present some approaches of the differential calculus in the Wasserstein space. We will also discuss recent advances on the calculus of variations on this space. Finally, we will explain how to build solutions to a nonlinear nonlocal equation on this space, the so-called master equation, which plays a key role in Mean Field Game theory.
On Differential Equations for Orthogonal Polynomials

Prof. Mama Foupouagnigni¹

¹ Université Yaounde I & AIMS Cameroon
Email: mfoupouagnigni@aims-cameroon.org

Timetable: 12 hrs. First lecture on January 23, 2018, 14:30 (dates already fixed, see calendar). Torre Archimede, Room 2BC/30

Course requirements:

Examination and grading:

SSD: MAT02, MAT03, MAT05

Aim:

Course contents: In the first step, we review properties of general orthogonal polynomials: Zeros, the Gauss quadrature, Three-term recurrence relations, and Christoffel-Darboux Formula.

In the second step, we state and prove some properties of the classical orthogonal polynomials such as: The orthogonality of the derivative, the second-order differential equation, the Rodrigues formula and the generating function. We provide explicitly the Gauss quadrature formula for the Chebyshev polynomials of the first, second, third and fourth kind and also illustrate the fact that the monic Chebyshev polynomials of the first kind of degree n is the polynomial of degree n deviating less from zero among all the monic polynomials of degree n.

In the third part, define the class of semi-classical orthogonal polynomials and study the Hahn problem consisting in proving that any family of orthogonal polynomials satisfying a second-order differential equation with polynomial coefficients is semi-classical.

In the fourth part, we derive the fourth-order differential equation satisfied by the associated classical orthogonal polynomials, and find the four linearly independent solutions of this differential equation. In this process, we point out some families of classical orthogonal polynomials whose first associated remains classical. Computer Algebra (Maple) will be used for some computing and verification.
Motion Planning in the Subriemannian framework

Jean-Paul Gauthier

1Université de Toulon, France
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Timetable: 16 hrs. First lecture on March 5, 2019, 11:00 (dates already fixed, see calendar), Torre Archimede, Room 2BC/30.

Course requirements: Basic notions in Differential Geometry and Analysis on manifolds

Examination and grading:

SSD: MAT/05

Aim: The "Motion Planning problem in Subriemannian geometry is the problem of $\epsilon$-approximating a smooth non admissible path by admissible ones. The (small) $\epsilon$ here refers to approximating up to Subriemannian distance less than $\epsilon$.

The typical "practical" applications of this problem concern kinematic robotics, obviously. The aim of the course is to give a short introduction on Subriemannian Geometry, then to present a complete theory of motion planning.

Course contents: Program of the course:

1. Sub-Riemannian Geometry (6h)
2. Corank one Motion Planning Problems (3h)
3. Corank two and three Motion Planning Problems (3h)
4. Convexity and Interpolation Entropy (3h)
5. Fast Trigonometric Oscillations (3h)
6. The Third Bracket (3h)
7. Goursat Structures (3h)

Gevrey asymptotics

Shingo Kamimoto

1Department of Mathematics, Hiroshima University
Email: kamimoto@hiroshima-u.ac.jp

Timetable: 16 hrs. First lecture on October 11, 2018, 15:00 (dates already fixed, see calendar), Torre Archimede, Room 2BC/30.

Course requirements:

Examination and grading:

SSD: MAT/05

Aim: The aim of this course is to study Gevrey asymptotics and its application to differential equations.

Course contents:
We first start from the fundamental of Gevrey asymptotic expansion. We then introduce the Borel-Laplace summation method, which is developed by J.-P. Ramis, J. Ecalle, W. Balser and several mathematicians. Since it directly connects formal structure to analytic structure of differential equations, it gives an effective tool to analyze asymptotic structure of analytic solutions at an irregular singular point of differential equations. We further extend it to the theory of multisummability: When we apply the Borel-Laplace summation method to actual problems, we need to handle multilevels of Gevrey asymptotics at once. Using the theory, we describe the structure of Stokes phenomena at an irregular singular point of differential equations.
Representation growth and zeta functions

Benjamin Klopsch

1Mathematisches Institut der Heinrich-Heine-Universität Düsseldorf, Germany
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Timetable: 16 hours. First lecture on November 6, 2018, 09:00 (dates already fixed, see calendar), Torre Archimede, Room 2BC/30.

Course requirements: Basic notions from algebra, number theory and group theory.
Further knowledge in one (or several) of the following areas is useful, but not strictly necessary: representation theory, p-adic numbers, profinite groups, analytic number theory. (We will introduce ad hoc all particular notions needed, but our treatment will feel less ad hoc, if one has seen these topics before.)

Examination and grading:

SSD: MAT/02

Aim:

Course contents:
The aim of the course is to introduce a general audience to a range of ideas and techniques that have found their way into asymptotic group theory during the last 20 years, in particular into the study of representation zeta functions of algebraic groups, arithmetic groups and compact p-adic groups. These zeta functions are Dirichlet generating functions reflecting the distribution of irreducible representations according to their degrees. We will approach the subject and some of the technical details by means of fairly concrete examples, such as the special linear groups over finite fields, over the complex numbers and over non-archimedean valuation rings. Proofs of corresponding general theorems will be sketched; they require the use of some 'black boxes' which we will set up precisely and motivate (but won’t have time to prove in full). Considerable emphasis will be placed on clarifying the basic definitions and notions to newcomers. As a road map we will use in a loose sense the fundamental paper of Larsen and Lubotzky on Representation growth of linear groups (2008). Hopefully the course will make this and other papers in the area more accessible.
Elliptic Curves and Modularity

Bao Viet Le Hung¹

¹ Dept. of Mathematics, Northwestern University, IL,
Email: bao.hung@northwestern.edu

Timetable: 16 hrs., February/March 2019, Torre Archimede, Room 2BC/30.

Course requirements: basic modular form, cohomology, local fields.

Examination and grading:

SSD: MAT/02 MAT/03

Aim: The aim of the course is to explain the statement of the modularity theorem, which asserts a deep connection between elliptic curves defined over Q and modular forms. This theorem is the heart of Wiles’ proof of Fermat’s Last Theorem.

Course contents: Topics to be discussed (which may be more or less fleshed out depending on interest and background of the audience)

1. Elliptic curves: basic theory (the group law, reductions mod p, the Tate module, etc.)
2. Modular forms: basic theory of modular forms, Hecke operators, modular curves and their Jacobians, Galois representations associated to modular forms.
3. (If time permits) Diophantine applications of the modularity theorem.

Syllabus: A good reference for the course is the book ”A first course on modular forms” by Diamond and Shurman, which roughly shares the same aim as this course.
Mathematical Theory of Control

Franco Rampazzo

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

Timetable: approximatively 16 hrs. First lecture on November 19, 2018, 08:30 (dates already fixed, see calendar), Torre Archimede, Room 2AB/40.

Course requirements:

Examination and grading: The final exams will consists either of a standard oral questioning on the main parts of the program or of a shortened recognition of the program togetrher with the dissertation on a research paper previously studied by the student.

SSD: MAT/05

Aim:
This course aims to provide the student with some basic tools, like non-linear ordinary differential equations (and their relation with first order ODE’s) and set separation, which allow one to attack the main questions of the so-called Theory of con- trol. The latter include minimum problems, which generalize one-dimensional Calculus of Variations to constrained dynamics, and the controllability question, namely the study of the set that can be reached starting from a given initial position by means of the controlled dynamics. Besides being a natural extension of some classical issues in Mathematical Anal- ysis and Differential Geometry, Control Theory is very much motivated by applications, from Aerospace Engeneering, to Medicine and Economics.

Course contents:
Courses offered within the Master’s Degree in Mathematics

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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Calculus of Variations

Prof. Luca Martinazzi
Università di Padova, Dipartimento di Matematica
Email: luca.martinazzi@math.unipd.it

Period: 2nd semester

Contents and other information:
https://didattica.unipd.it/off/2018/LM/SC/SC1172/010PD/SCP3050978/N0

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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:
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.

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Summer Courses in Perugia and Cortona

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

The Courses presented below (offered in the Catalogue of the Courses of the Doctoral School in Information Engineering) are suggested to the PhD Students but the attendance does not give acquisition of useful credits.

1. Technology entrepreneurship and lean start up

Teacher: Adriano La Vopa
E-mail: adriano@smartangle.it

The course will follow the below schedule. Every module is divided in two sessions of 2 hours, by exception of the last module, which consists of two sessions of 3 hours and a third one which is the Dragons Den (2 hours):

| Module 1 session 1 | Monday 04/02/2019   | 9.30-11.30 |
| Module 1 session 2 | Friday 08/02/2019   | 9.30-11.30 |
| Module 2 session 1 | Monday 11/02/2019   | 9.30-11.30 |
| Module 2 session 2 | Friday 15/02/2019   | 9.30-11.30 |
| Module 3 session 1 | Monday 18/02/2019   | 9.30-11.30 |
| Module 3 session 2 | Friday 22/02/2019   | 9.30-11.30 |
| Module 4 session 1 | Monday 25/02/2019   | 9.30-12.30 |
| Module 4 session 2 | Friday 01/03/2019   | 9.30-11.30 |
| Module 4 Dragons Den | Friday 15/03/2019 | 9.30-11.30 |

Course requirements: familiarity with basic math.

Aim: The course aims to develop a set of entrepreneurial skills in order to bring a simple idea from the aha moment till a business model. Students will learn how to create a solid model of their business around an idea with such a potential. They will learn how to use some tools for creating their own business, how to get feedback from the market and how to pitch it to possible investors. Students will apply a learn by doing approach and will work on practical cases driven by their own motivation.

Background material: No background material is necessary. The course will be held in English.

Modules:

- **Module 1:** Business, what's this? [4 h module 2 sessions]
  In this module students will learn: how a company is governed: managers, board members, shareholders and stakeholders; some examples of businesses: start up, scale up, spin up, spin off, spin out; customer centricity versus product development; phases of company life.
• **Module 2:** Building a business? [4 h module 2 sessions]
  In this module students will learn: creating a business by means of strategic tools: Business Model Canvas and all its parts; concept of Minimum Viable Product (MVP); business metrics; Intellectual Property (IP), protection and importance.

• **Module 3:** Getting the money [4 h module 2 sessions]
  In this module students will learn: funding opportunities like crowdfunding; the equity funding; business angels and venture capital.

• **Module 4:** Role game [8 h module 2 sessions]
  - Creating a venture from students ideas: this module will consist of 6 hours that will be aiming to working on a business model, meeting the customers and creating an MVP concept to be launched on the market.
  - Dragons Den session: real case pitching of 2 hours in front of a panel that will decide or not to invest in your company.

2. **Python programming for Scientific Engineering**

**Teacher:** Dr. Stefano Michieletto  
**e-mail:** michieletto@dei.unipd.it

**Timetable:** 20 hours. Class meets on Tuesday and Wednesday, 10:30 - 12:30. First lecture on Tuesday, November 20th, 2018. Room: DEI/D meeting room, Dept. of Information Engineering, DEI/D Building, 1st floor.

**Course requirements:** Backgrounds in computing with some object-oriented programming language: C++, Java, MATLAB, etc. If you are starting from scratch, please have a look at 3. or 4.

**Aim:** Python is an easy to learn and powerful programming language. Python is becoming more and more popular for scientific applications such as machine learning, integrate and interpolate numerical information, manipulate and transform data. The first objective of the course is to become familiar with Python syntax, environments and basic libraries. The learner will be guided in performing basic inferential data analyses and introduced to the application of common machine learning algorithms.

**Background material:** No background material is necessary. The course will be held in English.

**Modules:**

- **A Quick Tour of Python Language Syntax**
  - Python Basic Uses
  - What is different in Python?
• **Modules and Packages**
  - NumPy: Numerical Python
  - Pandas: Labeled Column-Oriented Data
  - Matplotlib: MATLAB-style scientific visualization
  - SciPy: Scientific Python

**References:**


   Online: https://aka.ms/BeginCodePython/downloads


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3. **Building a Research Career: A Success Story**

**Instructor:** Professor Fabrizio Nestola, Department of Earth Sciences, Universitá di Padova  
**e-mail:** fabrizio.nestola@unipd.it

**Time table:** TBD. Room: TBD.

**Abstract:** Fabrizio Nestola, Full Professor in Mineralogy at the University of Padova, ERC Grant recipient, explains how to start planning a successful career as an academic or industrial researcher right from the beginning of the Ph.D.

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4. **International Funding Opportunities for Young Researchers**

**Instructor:** International Research Office, Universitá di Padova  
**e-mail:** international.research@unipd.it
**Time table:** TBD. Room: 318 DEI/G, Dept. of Information Engineering, DEI/G Building, 3rd floor.

**Abstract:** Presentation of the International Research Office. How to build an international career for junior researchers: examples of successful CVs in major international funding programs. Hunting for information and funding opportunities: EURAXESS and Scival Funding research engines. Marie Skłodowska-Curie (MSCA) program with focus on Individual Fellowships (IF) and Co-Funding of Regional, National and International Programmes (COFUND) actions. European Research Council (ERC) funding scheme with focus on Starting Grant (StG). Additional individual funding opportunities to build and support an international career. Writing an individual proposal for a post-doctoral position.

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**PhD Educational Week on Transferable Skills**

**Timetable:** TBD (sometimes in June 2019).
Program: The final program will be available at the beginning of 2019. In the meantime, you may want to take a look at the program of PhDETSWeek 2018 (https://elearning.unipd.it/ufficiserviziapplicazioni/enrol/index.php?id=15, use your SSO credentials to authenticate and download the flyer).

**Aim:** the PhD Educational Week on Transferable Skills (PhDETSWeek) is a five-day event specifically conceived to help Ph.D. students to increase their soft-skills. Five main areas will be covered (one per day):

Area 1 - Communication/Public Speaking
Area 2 - Professional Development
Area 3 - Entrepreneurship
Area 4 - Personal Development
Area 5 - Funding opportunities and writing skills
Courses in collaboration with the Doctoral School on “Information Engineering”

https://www.dei.unipd.it/node/2399

for the Class Schedule see on pag. 6 of the DEI’s Catalogue at the address above

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.
Applied Linear Algebra

Prof. Fernando De Terán¹, Prof. Michael Karow²

¹ Universidad Carlos III de Madrid
e-mail: fteran@math.uc3m.es
² Technische Universität Berlin.
e-mail: karow@math.tu-berlin.de

Timetable: 16 hours. COURSE TO BE CONFIRMED

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.

SSD: Information Engineering

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:
- Review of some basic concepts of linear algebra and matrix theory.
- Gaussian elimination.
- LU factorization.
- Positive (semi) definite matrices and Cholesky factorization.
- Matrix exponential.
- Sylvester and Lyapunov equations, Riccati equation.
- Applications to Control Theory.

References:
1. Gilbert Strang’s linear algebra lectures, from M.I.T. on You Tube
3. Notes from the instructor
Distributed Optimization and Applications

Prof. Subhrakanti Dey

Signals and Systems, Uppsala University, Sweden
Email: Subhra.Dey@signal.uu.se

Timetable: 20 hrs. Class meets on Monday and Wednesday, 10:00 to 12:30, starting from June 17th, 2019. DEI/D meeting room, Dept. of Information Engineering, DEI/D Building, 1st floor.

Course requirements: Advanced calculus, and probability theory and random processes.

Examination and grading: A project assignment for students in groups of 2 requiring about 20 hours of work.

SSD:

Aim: The aim of this course is to introduce postgraduate students to the topical area of Distributed Optimization. As we enter the era of Big Data, engineers and computer scientists face the unenviable task of dealing with massive amounts of data to analyse and run their algorithms on. Often such data reside in many different computing nodes which communicate over a network, and the availability and processing of the entire data set at one central place is simply infeasible. One needs to thus implemented distributed optimization techniques with message passing amongst the computing nodes. The objective remains to achieve a solution that can be as close as possible to the solution to the centralized optimization problem. In this course, we will start with some history on the origins of distributed optimization algorithms such as the Alternating Direction Method of Multipliers (ADMM), discuss its properties, and applications to both convex and non-convex problems, and explore alternative techniques such as game theoretic methods as well as distributed stochastic optimization methods, and finish with discussions on very recent and largely open areas such as networked optimization and distributed machine learning algorithms. This course will provide a glimpse into this fascinating subject, and will be of relevance to graduate students in Electrical, Mechanical and Computer Engineering, Computer Science students, as well as graduate students in Applied Mathematics and Statistics, along with students dealing with large data sets and machine learning applications to Bioinformatics.

Course contents:

- Lectures 1 and 2: Precursors to distributed optimization algorithms: parallelization and decomposition of optimization algorithms (dual decomposition, proximal minimization algorithms, augmented Lagrangian and method of multipliers)
- Lecture 3: The Alternating Direction Method of Multipliers (ADMM): (Algorithm, convergence, optimality conditions, stopping criteria, constrained convex optimization)
- Lecture 4: Applications of ADMM to machine learning problems: 11 norm problems
- Lecture 5: ADMM based methods for solving consensus and sharing problems, ADMM for non-convex problems and examples
- Lecture 6: ADMM Implementation issues and numerical examples
- Lecture 7: Distributed optimization using non-cooperative game theory (basic theory of Nash equilibrium, existence, uniqueness and efficiency)
- Lecture 8: Distributed stochastic optimization and Stochastic Approximation algorithms
• Lecture 9: Networked Optimization (e.g. over a graph) and distributed optimization under communication constraints
• Lecture 10: Applications of distributed optimization to distributed machine learning: a survey for recent results

References:


Relevant recent papers will be referred to and distributed during the lectures.
Bayesian Machine Learning

Giorgio Maria Di Nunzio¹

¹ Department of Information Engineering
Email: dinunzio@dei.unipd.it

Timetable: Course of 20 hours. Class meets on Thursday (lecture room) and Friday (lab), 14:30-16:30. First lecture on Thursday, January 17th, 2019.
Room: Thursday lectures: 318 DEI/G, Dept. of Information Engineering, DEI/G Building, 3rd floor. Friday lectures: Te, Dept. of Information Engineering, DEI/G Building, 2nd floor.


Examination and grading: Homework assignments and final project.

SSD:

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.
   1. Mathematical framework
   2. Supervised and unsupervised learning

Bayesian decision theory
   1. Two-category classification
   2. Minimum-error-rate classification
   3. Bayes decision theory
   4. Decision surfaces

Estimation
   1. Maximum Likelihood Estimation
   2. Expectation Maximization
   3. Maximum A Posteriori
   4. Bayesian approach

Graphical models
   1. Bayesian networks
   2. Two-dimensional visualization

Evaluation
   1. Measures of accuracy
Introduction to Information Theory

Deniz Gunduz

Imperial College, London, UK
Email: d.gunduz@imperial.ac.uk

Timetable: 16 hrs. Class meets on Monday 11:00-13:00 and Tuesday 14:00-16:00 for four weeks starting October 08, 2018, with the exception of the week of Oct. 15 in which the classes will be on Thursday 11:00-13:00 and Friday 14:00-16:00. Department of Information Engineering, Via Gradenigo 6B, Room: Sala Riunioni DEI/D.

Course requirements:
Examination and grading: Grades will be based on a final exam
SSD: Information Engineering

Aim: The aim of this course is to introduce basic information theoretic concepts to students. We will start by introducing entropy, divergence, and, mutual information, and their mathematical properties. The rest of the course will be dedicated to illustrating engineering applications of these seemingly abstract quantities. We will see that entropy corresponds to the ultimate limit in data compression, divergence provides the best error exponent in hypothesis testing (i.e., binary classification), and mutual information sets the limit of how much data one can transmit reliably over a noisy communication channel.

Syllabus:

1. Week 1: Information measures
   - Day 1: Entropy, divergence, mutual information
   - Day 2: Properties of information measures (chain rule, data processing inequality, convexity)
2. Week 2: Lossless data compression
   - Day 1: Asymptotic equipartition property (AEP)
   - Day 2: Kraft inequality, Huffman coding and its optimality
3. Week 3: Information theory and learning
   - Day 1: Method of types, universal source coding, large deviations: Sanovs theorem
   - Day 2: Hypothesis testing, Steins lemma, Chernoff exponent
4. Week 4: Channel coding
   - Day 1: Channel capacity theorem, achievability, joint AEP
   - Day 2: Converse to channel coding theorem, feedback capacity, Joint source-channel coding

References:

Statistical Methods

Dr. Lorenzo Finesso¹

¹ email: lorenzo.finesso@unipd.it

Timetable: 24 hrs. Class meets on Mondays and Wednesdays, 10:30-12:30. First lecture on Monday, April 29th 2019. The May 1st lecture will be held on Thursday May 2nd. Room: DEI/D meeting room, Dept. of Information Engineering, DEI/D Building, 1st floor.

Course requirements: familiarity with basic linear algebra and probability.

Examination and grading: Homework assignments

SSD: Information Engineering

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. (a.k.a. relative entropy, Kullback-Leibler distance) between two probability measures.

- 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 la Csiszr Tusndy.


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 Marcuzzi¹

¹Dipartimento di Matematica Tullio Levi-Civita, Univ. Padova
e-mail: marcuzzi@math.unipd.it


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: INF/01

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 as well.

Course contents:
- definition of inverse problems, basic examples and numerical difficulties.
- numerical methods for QR and SVD and their application to the square-root implementation in PCA, east-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 in continuum mechanics; HPC implementations

References:
Applied Functional Analysis and Machine Learning

Prof. Gianluigi Pillonetto

1Department of Information Engineering, Univ. Padova
e-mail: giapi@dei.unipd.it

Timetable: Course of 28 hours (2 two-hours lectures per week): Classes on Monday 10:30-12:30 and Wednesday, 14:30-16:30. First lecture on Monday November 26th, 2018. Room: 318 DEI/G, Dept. of Information Engineering, DEI/G Building, 3rd floor with the exception of Jan. 9th, 2019, DEI/D meeting room, Dept. of Information Engineering, DEI/D Building, 1st floor

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.

SSD: Information Engineering

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:
Heuristics for Mathematical Optimization

Prof. Domenico Salvagnin

Department of Information Engineering, Padova
e-mail: dominiqs@gmail.com

Timetable: 20 hours. Class meets every Tuesday and Wednesday from 14:00 to 16:00. First lecture on February 26th, 2019. Room: DEI/D meeting room, Dept. of Information Engineering, DEI/D Building, 1st floor.

Course requirements:
- Moderate programming skills (on a language of choice)
- Basics in linear/integer programming.

Examination and grading: Final programming project.

SSD: Information Engineering

Aim: Make the students familiar with the most common mathematical heuristic approaches to solve mathematical/combinatorial optimization problems. This includes general strategies like local search, genetic algorithms and heuristics based on mathematical models.

Course contents:
- Mathematical optimization problems (intro).
- Heuristics vs exact methods for optimization (intro).
- General principle of heuristic design (diversification, intensification, randomization).
- Local search-based approaches.
- Genetic/population based approaches.
- The subMIP paradigm.
- Applications to selected combinatorial optimization problems: TSP, QAP, facility location, scheduling.

References:
1. Gendreau, Potvin Handbook of Metaheuristics, 2010
2. Marti, Pardalos, Resende Handbook of Heuristics, 2018
Analysis and Control of Multi-Agent Systems

Prof. Daniel Zelazo¹

¹ Faculty of Aerospace Engineering Technion Israel Institute of Technology
e-mail: dzelazo@technion.ac.il

Timetable: 20 hours. Class meets on Tuesday and Friday, 10:30 to 12:30 starting April 30th, 2019. Room: DEI/D meeting room, Dept. of Information Engineering, DEI/D Building, 1st floor.

Course requirements: TBA

Examination and grading: TBA

SSD: Information Engineering

Aim: Multi-agent systems, or networked dynamic systems (NDS), are systems composed of dynamic agents that interact with each other over an information exchange network. These systems can be used to perform team objectives with applications ranging from formation flying to distributed computation. Challenges associated with these systems are their analysis and synthesis, arising due to their decoupled, distributed, large-scale nature, and due to limited inter-agent sensing and communication capabilities. This course provides an introduction to these systems via tools from graph theory, dynamic systems and control theory. The course will cover a variety of modeling techniques for different types of networked systems and proceed to show how their properties, such as stability and performance, can be analyzed. The course will also explore techniques for designing these systems. The course will also cover real-world applications by presenting recent results obtained in the distributed formation control and localization of multi-robot systems.

Course contents:

- Lecture 1: Introduction to NDS; fundamentals of graph theory; algebraic graph theory
- Lectures 2-3: Consensus protocol - undirected, directed, switching, non-linear
- Lectures 4-5: Formation control - rigidity theory, distance constrained formations
- Lectures 6-7-8: Formation control/Localization - bearing rigidity theory, bearing-only formations, network localization
- Lectures 9-10: Advanced topics - survey of important results, applications, and open problems

References: