Graduate Course in Information Engineering: Ph.D. program
Department of Information Engineering
University of Padova

Course Catalogue
2016-2017
Requirements for Ph.D. Students of the Graduate Course in Information Engineering:

1. Students are required to take courses from the present catalogue for a minimum of 80 hours (20 credits) during the first year of the Ph.D. program.

2. Students are required to take for credit at least one out of the following three basic courses “Applied Functional Analysis”, “Applied Linear Algebra”, and “Statistical Methods” during the first year of the Ph.D. program. Moreover, the other two courses are strongly recommended to all students.

3. After the first year, students are strongly encouraged to take courses (possibly outside the present catalogue) for at least 10 credits (or equivalent) according to their research interests.

Students are requested to enroll in each course they intend to take at least one month before the class starts. To enroll, it is sufficient to send an e-mail message to the secretariat of the course at the address calore@dei.unipd.it

Students are expected to attend classes regularly. Punctuality is expected both from instructors and students.

Instructors have to report to the Director of Graduate Studies any case of a student missing classes without proper excuse.

In addition to the courses listed in this catalogue the Graduate Course will promote and organize additional courses and series of lectures, of potential interest to PhD Students, which however will not be valid for credits; these will be advertised through the Graduate Course webpage (see the Seminars and Seasonal Schools section on the web page http://www.dei.unipd.it/en/phd) as well as using the PhD Students’ mailing list.
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1 The FFT and its use in digital signal processing

Instructor: Prof. S. Pupolin, Dept. Information Engineering, University of Padova, e-mail: pupolin@dei.unipd.it

Aim: The course is intended to give a survey of the basic aspects of signal domains and the effects in digital signal processing in terms of signal distortion.

Topics:

- Review of some notions on Fourier Transform in different time domains (continuous and discrete; aperiodic and periodic). The FFT.
- Definitions and properties of signal energy, convolution, correlation in the time domains and their Fourier transforms
- Signal transformations. Linear transformations. Elementary transformations: sampling and interpolation. Up- and Down-Periodization
- Numerical computation of the Fourier transform of a continuous-time finite energy signal via FFT
- Numerical computation of the convolution (correlation) of two continuous-time finite energy signals via FFT.
- Bandlimited continuous time signal filtering: from analog filters to a mix of analog and digital filters.
- Example of applications: OFDM modulation and cyclic prex.
- Channel estimation in OFDM systems
- Estimate of power spectrum for finite power signals. From definitions to numerical computation.
- FFT output SNR for a quantized input signal. Discussion

References:
All the necessary material can be found in G. Cariolaro book: “Unified Signal Theory”, (Springer-Verlag, London 2011).

**Time table:** 20 hours, 5 credits. Class meets every Monday and Friday from 10:30 to 12:30. First lecture on Monday, October 17th, 2016. Room 318 DEI/G (3-rd oor, Dept. of Information Engineering, via Gradenigo Building).

**Course requirements:** Basic knowledge of signals and systems.

**Examination and grading:** Homeworks and final exam.
2 Fluid mechanics for the functional assessment of cardiovascular devices

Instructor: F. M. Susin, Dept. ICEA, University of Padua, e-mail: francescamaria.susin@unipd.it

Aim: The course is intended to give a survey of research approaches for the assessment of cardiovascular medical devices. Emphasis will be given to methods and techniques adopted for in vitro analysis of hemodynamic performance of prosthetic heart valves and total artificial heart.

Topics: Review of basic fluid mechanics concepts. Fluid mechanics of prosthetic heart valves (PHVs) and ventricular assist devices (VADs). Pulse duplicators for in vitro testing of PHVs and mock circulation loops for pre-clinical evaluation of VADs. Experimental techniques for the assessment of PHVs and VADs performance. CFD for functional assessment of PHVs and VADs.

References:


**Time table:** Course of 16 hours. Lectures (2 hours) on Wednesday 10:30 - 12:30. First lecture on Wednesday, Oct. 19, 2016. Meeting Room DEI/G (3-rd floor, Dept. of Information Engineering, via Gradenigo Building).

**Course requirements:** Fundamentals of Fluid Dynamics.

**Examination and grading:** Homework assignment with final discussion.
3 Information-theoretic Methods in Security

Instructor: Nicola Laurenti, Department of Information Engineering, Univ. of Padova, e-mail: nil@dei.unipd.it

Aim: The class aims at providing the students with an information theoretic framework that will allow formal modeling, understanding of the fundamental performance limits, and derivation of unconditionally secure mechanisms for several security-related problems.

Topics:


- Secrecy without cryptography. The wiretap channel model. Rate-equivocation pairs. Secrecy rates. Secrecy capacity for binary, Gaussian and fading channel models.

- Security from uncertainty. Secret key agreement from common randomness on noisy channels. Information theoretic models and performance limits of quantum cryptography.


- The gossip game. Broadcast and secrecy models in multiple access channels. The role of trusted and untrusted relays.


- The jamming game. Optimal strategies for transmitters, receivers and jammers in Gaussian, fading and MIMO channels.

- Alea iacta est. Secure and true random number generation. Randomness extractors and smooth guessing entropy.
• **Writing in sympathetic ink.** Information theoretic models of steganography, watermarking and other information hiding techniques.

• **Leaky buckets and pipes.** Information leaking and covert channels. Timing channels.

• **The dining cryptographers.** Privacy and anonymity. Secure multiparty computation.

• **Putting pieces together.** Universally composable security in the computational, information theoretic and quantum information frameworks

• **Information theoretic democracy.** Privacy, reliability and verifiability in electronic voting systems.

• **The Big Brother.** An information theoretic formulation of database security: the privacy vs utility tradeoff.

**References:**


• A short list of reference papers for each lecture will be provided during class meetings.

**Time table:** Course of 20 hours. Class meets every Tuesday and Thursday from 10:30 to 12:30. First lecture on Tuesday, October 18th, 2016. Room DEI/D, 1st floor, Dept. of Information Engineering, via Gradenigo Building.

**Course requirements:** Basic notions of Information Theory (e.g., those from the Telecomunicazioni class in the Corso di Laurea in Ingegneria dell’Informazione)

**Examination and grading:** Each student (or a small group) must submit a project, and grading will be based on its evaluation. Students are encouraged to work from an information theoretic point of view on a security problem related to their research activities.
4 Applied Functional Analysis and Machine Learning

**Instructor:** Prof. G. Pillonetto, Dept. Information Engineering, University of Padova, e-mail: giapi@dei.unipd.it

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

**Topics:**


**Course requirements:**
1. The classical theory of functions of real variable: limits and continuity, differentiation and Riemann integration, infinite series and uniform convergence.

2. The arithmetic of complex numbers and the basic properties of the complex exponential function.

3. Some elementary set theory.


All the necessary material can be found in W. Rudin’s book Principles of Mathematical Analysis (3rd ed., McGraw-Hill, 1976). A summary of the relevant facts will be given in the first lecture.

References:


Time table: 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 23rd, 2016. Sala Riunioni 318 DEI/G 3-rd floor, via Gradenigo 6).

Examination and grading: Homework assignments and final test.
5 Bayesian Machine Learning

Instructor: Giorgio Maria Di Nunzio, e-mail: dinunzio@dei.unipd.it

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 practical problems.

Topics:

- Introduction of classical machine learning problems.
  - Mathematical framework
  - Supervised and unsupervised learning
- Bayesian decision theory
  - Two-category classification
  - Minimum-error-rate classification
  - Bayes risk
  - Decision surfaces
- Estimation
  - Maximum Likelihood Estimation
  - Maximum A Posteriori
  - Bayesian approach
- Graphical models
  - Bayesian networks
  - Two-dimensional probabilistic model
- Evaluation
  - Measures of accuracy
  - Statistical significance testing
References:


(supporting material available at http://amlbook.com/support.html)

(freely available and supporting material at http://www.inference.phy.cam.ac.uk/mackay/itila/)

(freely available at http://web4.cs.ucl.ac.uk/staff/D.Barber/pmwiki/pmwiki.php?n=)

(supporting material http://www.cs.ubc.ca/~murphyk/MLbook/)

Time table: Course of 20 hours. Tentative schedule: Class meets every Thursday from 14:30 to 16:30 and Friday from 11:30 to 13:30. First lecture on Thursday, 12th January, 2017. Room DEI/G, 3-rd floor, Dept. of Information Engineering, via Gradenigo Building.


Examination and grading: Homework assignments and final project.
6 Technology entrepreneurship and lean start up

Instructor: Dr. Ruggero Frezza, Dr. William Vespi, M31 Spa, Padova, e-mail: ruggero.frezza@m31.com

Aim: The course will present how to bring an high technology idea to market applying the lean start up methodology. The aim is to give the students a basic set of tools to launch their own business if they will ever wish to do so. The course will apply a learn by doing approach and the instructors will pose real challenges to the students in hackathon style events.

Topics:

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

- **Corporations** What is a company and how it is governed. Managers, board members, shareholders and stakeholders. What is a start up company. Customer versus product development. The phases of the life of a company.

- **Market opportunity analysis** Business Model Canvas; Value proposition; customer segments; customer development process; minimum viable product; business metrics.

- **Intellectual property strategy** When and why deposit a patent application. The process of a patent application. The value of a patent.

- **Funding the start up phase** Crowdfunding; equity funding; business angels and venture capital.

- **Call to action** Presentation of real challenges in a hackathon like events.

- **Venture creation** Launch of the company; leave the building and experiment with the customers.

- **Funding the growth phase** Debt; private equity; IPO.

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

**Course requirements:** familiarity with basic linear algebra.

**Examination and grading:** homework and take home exam.
7 Tissue Engineering: Principles and Applications

**Instructor:** Prof. Andrea Bagno, Department of Industrial Engineering, University of Padova. e-mail: andrea.bagno@unipd.it

**Aim:** The course will provide the basic knowledge of materials and methods for tissue engineering (TE) techniques. The course will also present some practical applications with regard to the production of engineered tissues.

**Topics:**

1. Fundamentals of TE.
2. Engineering biomaterials for TE.
4. Regeneration templates.
5. TE of biological tissues (cartilage, hearth valves, bone).

**References:**


Other material and research papers will be available online for download.


**Course requirements:** Basic courses of chemistry, biology and physiology, biomaterials.
Examination and grading: Homework assignments and final test.
8 Real-Time Systems and applications

Instructor: Gabriele Manduchi, Consiglio Nazionale delle Ricerche
e-mail: gabriele.manduchi@igi.cnr.it

Aim: The course will provide an insight in the realm of real-time system. Knowledge in this field is normally fragmented and scattered among different engineering disciplines and computing sciences, and the the aim of the course is present aspects related to theory and practice in a way which is holistic enough to prepare graduates to embark on the development of real-time systems, frequently complex and imposing safety requirements. For this reason, after presenting in the first part of the course a surveys of related topics, including scheduling theory and real-time issues in operating systems, the control system of a Nuclear Fusion experiment will be presented as Use Case and analyzed in the second part of the course.

Topics:

- Concurrent Programming Concepts Remind: the role of parallelism and multithreading, deadlocks, interprocess communication, network communication.
- Real-time scheduling analysis: task-based scheduling, schedulability analysis based on utilization, schedulability analysis based on response time analysis, task interaction and blocking.
- Internal structures and operating principles of Linux real-time extensions.
- Data Acquisition systems: general concepts and architectures.
- An introduction of massive parallel operation in real-time applications using GPUs.
- Analysis of a real-time control system for nuclear fusion experiment.

References:


**Time table:** Course of 20 hours. Class meets every Tuesday and Thursday from 8:30 to 10:30. First lecture on Tuesday, January 24, 2017. Room DEI/G (3-rd floor, Dept. of Information Engineering, via Gradenigo Building).

**Course requirements:** Basic knowledge of Operating System and concurrent programming concepts.

**Examination and grading:** Each student will develop a case study, possibly related to his/her own research activity, addressing some topic presented in the course.
9 Low Power Wide Area Networks

Instructor: Prof. Lorenzo Vangelista, e-mail: lorenzo.vangelista@unipd.it

Aim: Introduce and explain the major characteristics of a new paradigm in the wireless sensors and actuators networks: the Low Power Wide Area Networks (LPWAN)

Topics:

- The concept of Internet of Things (IoT)
- The connectivity as an integral part of the IoT: the regulatory framework, licensed vs unlicensed bands, standardisation bodies
- The connectivity as an integral part of the IoT: cellular networks and mesh networks
- The connectivity as an integral part of the IoT: the new paradigm of LPWANs
- Review of current LPWAN systems: SigFox, Ingenu, Waviot etc.
- Review of one of the most promising LPWAN systems: Lo-Ra; system architecture, protocols, performance
- NB-IoT: the cellular alternative to LPWANs

References:


2 Long-Range IoT Technologies: The Dawn of LoRa, L. Vangelista, A. Zanella, M. Zorzi, Future Access Enablers for Ubiquitous and Intelligent Infrastructures, 2015

3 The challenges of M2M massive access in wireless cellular networks A. Biral, M. Centenaro, A. Zanella, L. Vangelista, M. Zorzi - Digital Communications and Networks, 2015
**Time table:** Course of 16 hours. Class meets every Tuesday and Thursday from 16:30 to 18:30. First lecture on January 31, 16:30, 2017. Room DEI/D, 1st floor, Dept. of Information Engineering, via Gradenigo Building.

**Course requirements:** Basic knowledge of (wireless) communication systems

**Examination and grading:** Project work assigned by the instructor
10 Computational Inverse Problems

**Instructor:** Fabio Marcuzzi, Dept. of Mathematics, University of Padova  
e-mail: marcuzzi@math.unipd.it

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

**Topics:**

- 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, 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:**

[1] F.Marcuzzi ”Analisi dei dati mediante modelli matematici”,  
http://www.math.unipd.it/~marcuzzi/MNAD.html

**Time table:** Course of 20 hours (2 two-hours lectures per week): Classes on Monday and Wednesday, 10:30 - 12:30. First lecture on Monday February 27th, 2017. Room DEI/G, 3-nd 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.
11 Diagnostics of Electron Devices

**Instructor:** Proff. Giovanna Mura, Massimo Vanzi - Department of Electrical and Electronic Engineering (DIEE) University of Cagliari  
e-mail: gmura@diee.unica.it vanzi@diee.unica.it

**Aim:** this course provides an overview of the Failure Analysis techniques for the diagnostics of electron devices.

Failure analysis is the process of analyzing the failed electron devices to determine the reason for degraded performance or catastrophic failure and to provide corrective actions able to fix the problem.

It is a proactive tool with three fundamental tasks: 1) Technical/scientific: 2) Technological 3) Economical. The purpose of this course is to teach what Failure Analysis should be and should do, to show how and why it often does not, to state that F.A. has Logics and has Rules.

Microscopy, in its several forms (optical, electron, scanning, transmission, emission, ionic) and tools is the playground for practical FA, and its fundamentals will be described. Device basic technology, working principle and failure physics are the other pillars for a successful study.

Several case studies will be proposed with the aim to demonstrate that if sometimes Failure Analysis looks unclear or not problem solving is merely because it was badly conducted.

**Topics:** The course will cover the following topics:

a) Reverse engineering  
b) Failure modes and failure mechanisms  
c) Principles and fundamental methods in Electron Microscopy  
d) Methodology for the Failure Analysis

**References:** Failure Analysis of Integrated Circuits - Tools and Techniques
Time table: Course of 16 hours. Class meets starting March 6th, 2017 with the following schedule: March 6th from 15.30 to 17:30, March 7th from 9.30 to 11:30, March 13th from 15.30 to 17:30, March 14th from 13.30 to 15:30, March 23rd from 14.30 to 16:30, March 24th from 9.30 to 11:30, March 30th from 14.30 to 16:30 March 31st from 9.30 to 11:30.

Room DEI/G, 3rd floor, Dept. of Information Engineering, via Gradenigo Building.

Course requirements: Electron Devices, Microelectronics, Optoelectronics devices.

Examination and grading: Written test/ presentation of a report at the end of the course.
12 Applied Linear Algebra

Instructors: Prof. F. de Terán, Universidad Carlos III de Madrid, 
e-mail: fteran@math.uc3m.es . 
Prof. Michael Karow, Technische Universität Berlin, 
e-mail: karow@math.tu-berlin.de

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.

Topics:

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

Time table: Course of 16 hours.
• First part (De Terán): Class meets on Tuesday and Thursday, from 10.30 to 12.30. First Lecture on March 14th, 2017

• Second part (Karow): Class meets on Tuesday and Thursday, from 10.30 to 12.30. First Lecture on March 28th, 2017

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.
13 Physics and operation of heterostructure-based electronic and optoelectronic devices

Instructors: E. Zanoni, M. Meneghini and C. De Santi

e-mail: \{gauss,menego,desantic\}@dei.unipd.it

Aim: This course provides an introduction to the physics and operating principles of advanced electronic and optoelectronic devices based on compound semiconductors. These devices are particularly important for several applications: high electron mobility transistors (HEMTs) represent excellent devices for the realization of high frequency communication systems, radars, satellite applications, and high efficiency power converters. On the other hand, LEDs and lasers are high-efficiency monochromatic light sources, that can be used both for lighting applications (with a considerable energy saving), in the biomedical field, and in in photochemistry. Special focus will be given to Gallium Nitride (GaN) based devices, that represent the most promising devices for future power electronics applications. This course will focus on the main aspects related to the physics of heterostructures, on the recombination processes in semiconductors, on carrier transport in heterostructures, on the structure and operating principles of MESFET, HEMTs, GITs, on the trapping and reliability in compound semiconductor devices, on the operating principles of LEDs and lasers, and on parasitics and reliability in LEDs and lasers. An overview of real applications highlighting the capabilities of these devices will also be given.

Topics:

- physics of heterostructures, band diagrams, carrier transport in heterostructures;
- recombination processes in semiconductors;
- properties of compound semiconductors;
- basic structure of heterojunction transistors, MESFET, HEMT, GIT;
- parasitics and reliability in HEMTs, LEDs and lasers;
• operating principles of LEDs and lasers;
• methods for advanced characterization of heterojunction based devices;
• applications of GaN based HEMTs, LEDs and lasers;
• modeling of semiconductor-based devices

References:


Time table: Course of 20 hours. (2 two-hours lectures per week) Classes on Monday 14:30 - 16:30 and Thursday, 16:30 - 18:30. First lecture on Monday March 20, 2017

Course requirements: Introductory course of device physics: Microelectronics, Optoelectronic and Photovoltaic Devices Examination and grading: Written test at the end of the course
In this course, we will study the use of a nonlinear projection operator in the development of a novel function space approach for the optimization of trajectory functionals. Given a bounded state-control trajectory of a nonlinear system, one may make use of a simple (e.g., linear time-varying) trajectory tracking control law to explore the set of nearby bounded state-control trajectories. Such a trajectory tracking control system defines a nonlinear projection operator that maps a set of bounded curves onto a set of nearby bounded trajectories.

We will use the projection operator approach to develop a Newton descent method for the optimization of dynamically constrained functionals. By projecting a neighboring set of state-control curves onto the trajectory manifold and then evaluating the cost functional, the constraint imposed by the nonlinear system dynamics is subsumed into an unconstrained trajectory functional. Attacking this equivalent optimization problem in an essentially unconstrained manner, we will discover an algorithm defined in function space that produces a descending sequence in the Banach manifold of bounded trajectories. The specific computations for this algorithm will be implemented by solving ordinary differential equations.

Of special interest is the trajectory representation theorem: trajectories near a given trajectory can be represented uniquely as the projection of the sum of that trajectory and a tangent trajectory, providing a local chart for the trajectory manifold. The composition of the cost functional with this mapping is thereby a mapping from the Banach space of tangent trajectories into the real numbers and it is this local mapping that may or may not possess (local) convexity properties. When the second Frechet derivative of this mapping is positive definite (in an appropriate sense), the mapping is locally convex which is useful for many applications including the existence of a Newton descent direction, second order sufficient condition (SSC) for optimality, quadratic convergence, and continuous dependence of optimal trajectories on
We will make use of the PRojection Operator based Newton method for Trajectory Optimization (PRONTO) to do some numerical ”trajectory exploration” on some interesting nonlinear systems, including possible student selected systems. Throughout the course, various concepts will be illustrated with examples and followed by homework assignments designed to enhance understanding.

References: Lecture notes and references will be posted on the web site of the course.


Course requirements: familiarity with basic linear algebra.

Examination and grading: homework and final project.
15 Statistical Methods

Instructor: Dr. Lorenzo Finesso, Istituto di Elettronica e di Ingegneria dell’Informazione e delle Telecomunicazioni, IEIIT-CNR, Padova, e-mail: lorenzo.finesso@unipd.it

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.

Topics:

- **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 Nonnegative 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.

- **Applications to stochastic processes.** Introduction to HMM (Hidden Markov Models). Maximum likelihood estimation for HMM via the EM method. If time allows: derivation of the Burg spectral estimation method as solution of a Maximum Entropy problem.
**References:** A set of lecture notes and a complete list of references will be posted on the web site of the course.

**Time table:** Course of 24 hours. Class meets every Monday and Wednesday from 10.30 to 12.30. First lecture on April, 19th, 2017. Room DEI/G, 3rd floor, Dept. of Information Engineering, via Gradenigo Building.

**Course requirements:** familiarity with basic linear algebra.

**Examination and grading:** homework and take home exam.