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

Course Catalogue

2013

Requirements for Ph.D. Students of the Graduate School of 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 have to enroll in the courses 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 school 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.

Contents

1 Applied Functional Analysis

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, operator theory in Hilbert spaces, regularization theory and inverse problems.

Topics:

1. *Review of some notions on metric spaces and Lebesgue integration*: Metric spaces. Open sets, closed sets, neighborhoods. Convergence, Cauchy sequences, completeness. Completion of metric spaces. Review of the Lebesgue integration theory. Lebesgue spaces.

2. *Banach and Hilbert spaces*: Normed spaces and Banach spaces. Finite dimensional normed spaces and subspaces. Compactness and finite dimension. Bounded linear operators. Linear functionals. The finite dimensional case. Normed spaces of operators and the dual space. Weak topologies. Inner product spaces and Hilbert spaces. Orthogonal complements and direct sums. Orthonormal sets and sequences. Representation of functionals on Hilbert spaces. Hilbert adjoint operator. Self-adjoint operators, unitary operators.

3. *Compact linear operators on normed spaces and their spectrum*: Spectral properties of bounded linear operators. Compact linear operators on normed spaces. Spectral properties of compact linear operators. Spectral properties of bounded self-adjoint operators, positive operators, operators defined by a kernel. Mercer Kernels and Mercer's theorem.

4. *Reproducing kernel Hilbert spaces, inverse problems and regularization theory*: Reproducing Kernel Hilbert Spaces (RKHS): definition and basic properties. Examples of RKHS. Function estimation problems in RKHS. Tikhonov regularization. Basic concepts of convex analysis. Primal and dual formulation of loss functions. Regularization networks. Support vector regression and classification. Support vector classification. Representer theorem.

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.

4. A bit of linear algebra.

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:

[1] W. Rudin. Real and Complex Analysis, McGraw Hill, 2006

[2] E. Kreyszig. Introductory Functional Analysis with Applications, John Wiley and Sons , 1978

[3] G. Wahba. Spline models for observational data. SIAM, 1990

[4] C.E. Rasmussen and C.K.I. Williams. Gaussian Processes for Machine Learning. The MIT Press, 2006

[5] R.T. Rockafellar. Convex analysis. Princeton University Press, 1996

Time table: Course of 28 hours (2 two-hours lectures per week): Classes on Tuesday and Thursday, 10:30 - 12:30. First lecture on Tuesday September 17th, 2013. Room DEI/G (3-rd floor, Dept. of Information Engineering, via Gradenigo Building).

Examination and grading: Homework assignments and final test.

2 Applied Linear Algebra

Instructor: Harald Wimmer, University of Würzburg, Germany
e-mail: `wimmer@mathematik.uni-wuerzburg.de`

Aim: We study concepts and techniques of linear algebra that are important for applications and computational issues. A wide range of exercises and problems will be presented such that a practical knowledge of tools and methods of linear algebra can be acquired.

Topics:

- *Kronecker products*
- *Linear matrix equations (Sylvester equations, Lyapunov equations)*
- *Systems of linear difference and differential equations with applications (e.g. damped linear vibrations)*
- *Structured matrices (e.g. stochastic and doubly stochastic matrices)*

References:

[1] E. Gregorio and L. Salce. *Algebra Lineare.* Edizioni Libreria Progetto, Padova, 2005.

[2] A.J. Laub. *Matrix Analysis for Scientists and Engineers*, SIAM, Philadelphia, 2005.

[3] C.D. Meyer. *Matrix Analysis and Applied Linear Algebra*, SIAM, Philadelphia, 2000.

Course requirements: A good working knowledge of basic notions of linear algebra, as presented e.g. in [1]. Proficiency in MATLAB is essential.

Time table: Course of 16 hours (2 two-hour lectures per week): Classes on Tuesday and Thursday, 14:30 – 16:30. First lecture on April 9, last lecture on May 7, 2013.

Classroom: Pe (Dept. of Information Engineering).

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

3 Brownian motion and noise in physical devices

Instructor: Michele Pavon, e-mail: `pavon@math.unipd.it`

Aim: Elements of stochastic calculus. Fundamental models of physical Brownian motion and electric networks with noisy resistors.

Topics: Topics will be selected from those listed below.

- *Probabilistic background:*
  1. Physical Brownian motion.
  2. Construction of the Wiener process.
  3. Basic properties of the Wiener process.
  4. Finite-energy Markov diffusions. The change of variables formula.
  5. The Fokker-Planck equation.
  6. Square-integrable martingales.
- *Dynamical theories of Brownian motion:*
  1. Langevin.
  2. The Einstein-Smoluchowsky model, Einstein's fluctuation-dissipation relation.
  3. The Nyquist-Johnson noisy resistor.
  4. The Ornstein-Uhlenbeck model.
  5. Gibbs postulate and the Maxwell-Boltzmann distribution.
  6. Random oscillators.
  7. Maximum Entropy Problems and H-theorem.

References:

[1] M. Pavon, Lecture Notes on Brownian Motion, 2000 (will be distributed to students).

[2] E. Nelson. *Dynamical Theories of Brownian Motion.* Princeton University Press, Princeton, 1967.

[3] I. Karatzas and S. E. Shreve, *Brownian Motion and Stochastic Calculus*, 2nd edition, Springer-Verlag, New York, 1991.

[4] B. Øskendal, *Stochastic Differential Equations*, 4th edition, Springer, 1995.

[5] T. M. Cover and J. A. Thomas, *Elements of Information Theory*, 2nd edition, Wiley, 2006.

Time table: Course of 20 hours. Class meets every Tuesday and Thursday from 2:30 to 4:30. First lecture on Tuesday, Sept. 3rd , 2013. Room DEI/G (3-rd floor, Dept. of Information Engineering, via Gradenigo Building).

Course requirements: Basic background in probability.

Examination and grading: 4 Homework assignments (to be handed in one week later).

4 Distributed computer platforms

Instructor: Massimo Maresca. e-mail: `massimo.maresca@unipd.it`

Aim: To introduce the techniques that support high speed networking and distributed platforms. The course consists of two parts. The first part, which includes the first half of the lectures, describes the evolution of high speed networking from the basic datagram based model, implemented by TCP/IP, to the cell based model, implemented by ATM, to the VLAN model, implemented by Ethernet, up to the VPN model implemented by MPLS. The second part, which includes the second half of the lectures, covers the application issues related to the implementation of distributed platforms. In particular starting from the basic programming language support for network communication, the course presents the issues related to the design and the implementation of Web Applications and Web Services and describes the functionalities of a basic servlet container.

Topics:

- Review of TCP/IP model, of the Ethernet model and of the basic networking mechanisms, Network Architecture: Access, Backhaul, Backbone, Network Organization: layers and planes
- From Circuit Switching to Packet Switching to Frame Switching to Cell Switching: from ATM to IP
- From LANs to VLANs and Spanning Tree Algorithms
- Multi Protocol Label Switching and Virtual Private Networks
- Programming Language support for network communication
- Specification, Requirements, Design and Implementation of a simple servlet container
- Web Application design using servlet containers
- Web Service design and implementation

References:

[1] Andrew Tanenbaum, Computer Networks

[2] ATM Standard

[3] IEEE 802.1D,IEEE 802.1Q, IEEE 802.1ad, IEEE 802.1ah standards

[4] MPLS RFC 3031

[5] Tomcat Servlet Container, http://tomcat.apache.org

Time table: Course of 20 hours. Class meets every Monday and Tuesday from 2:30 to 4:30. First lecture on Monday, February 18, 2013. Room DEI/G (3-rd floor, Dept. of Information Engineering, via Gradenigo Building).

Course requirements: Basic knowldge of Computer networks protocols and techniques.

Examination and grading: Laboratory project and oral presentation.

5 E. M. Waves in Anisotropic Media

Instructor: Carlo Giacomo Someda, Dept. of Information Engineering, Univ. of Padova
e-mail: someda@dei.unipd.it.

Aim: To go beyond the standard limitations of typical courses on e.m. waves. In all those that are currently taught at our Department, and in comparable Universities, the medium where waves propagate is always assumed to be linear and isotropic. This is a severe limitation, which hinders, nowadays, comprehension of how many practical devices work, as well as of some physical concepts that are relevant even to philosophy of science (e.g., reciprocity).

Topics:

1. Features shared by all linear anisotropic media: mathematical description in terms of dyadics. Energy transport in anisotropic media: waves and rays.
2. Propagation of polarization in anisotropic media: the Jones matrix, the Mueller matrix.
3. Linearly birefringent media: Fresnels equations of wave normals. The indicatrix.
4. Applications: fundamentals of crystal optics.
5. Gyrotropic media: constitutive relations of the ionosphere and of magnetized ferrites. The Appleton-Hartree formula
6. Faraday rotation and its applications.
7. Circular birefringence vs. reciprocity in anisotropic media
8. Introduction to the backscattering analysis of optical fibers.

References:

[1] C. G. Someda, Electromagnetic Waves, 2nd Edition, CRC Taylor & Francis, Boca Raton, FL, 2006

[2] M. Born and E. Wolf, Principles of Optics: Electromagnetic Theory of Propagation, Interference and Diffraction of Light, 6th Ed., Pergamon Press, 1986.

[3] J. A. Kong, Electromagnetic Wave Theory, 2nd Ed., Wiley, 1990.

[4] J.F. Nye, Physical Properties of Crystals: Their Representation by Tensors and Matrices, paperback edition, Clarendon Press, 1985.

[5] C.G. Someda and G. I. Stegeman, eds., Anisotropic and Nonlinear Waveguides, Elsevier, 1992.

Time table: Course of 20 hours (two lectures of two hours each per week). Class meets every Wednesday and Thursday from 2:30 to 4:30. First lecture on Tuesday, May 8, 2013. Room DEI/G (3-rd floor, Dept. of Information Engineering, via Gradenigo Building).

Course requirements: Basic knowledge of e.m. wave propagation in linear isotropic media. Fundamentals of linear algebra.

Examination and grading: Weekly homework assignment. Final mini-project.

6 Fluid mechanics for the functional assessment of cardiovascular devices

Instructor: Francesca Maria Susin, Dept. ICEA, University of Padua.
e-mail: `susy@idra.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:

[1] M. Grigioni, C. Daniele, G. D'Avenio, U. Morbiducci, C. Del Gaudio, M. Abbate and D. Di Meo. Innovative technologies for the assessment of cardiovascular medical devices: state of the art techniques for artificial heart valve testing. *Expert Rev. Medical Devices*, 1(1) : 81-93, 2004.

[2] K.B. Chandran, A.P. Yoganathan and S.E. Rittgers. Biofluid Mechanics: the uman circulation. CRC Press, Boca Raton, FL, 2007.

[3] A.P. Yoganathan, K.B. Chandran and F. Sotiropoulos. Flow in prosthetic heart valves: state of the heart and future directions. *Annals of Biomedical Engineering*, 33(12) : 1689-1694, 2005.

[4] A.P. Yoganathan, Z. He and S. Casey Jones. Fluid mechanics of heart valves. *Ann. Rev. Biomed. Eng.*, 6 : 331-362, 2004.

[5] A.P. Yoganathan and F. Sotiropoulos. Using computational fluid dynamics to examine the hemodynamics of artificial heart valves. *Business briefing: US cardiology 2004*: 1-5, 2004.

[6] V. Barbaro, C. Daniele and M. Grigioni. Descrizione di un sistema a flusso pulsatile per la valutazione delle protesi valvolari cardiache. ISTISAN Report 91/7, Rome, Italy, 1991.

[7] M. Grigioni, C. Daniele, C. Romanelli and V. Barbaro. Banco di prova per la caratterizzazione di dispositivi di assistenza meccanica al circolo. ISTISAN Report 03/21, Rome, Italy, 2003.

Time table: Course of 12 hours. Class meets on Wednesday from 8:30 to 10:30. First lecture on Wednesday, October 2, 2013. Room DEI/G (3-rd floor, Dept. of Information Engineering, via Gradenigo Building).

Course requirements: Fundamentals of Fluid Dynamics.

Examination and grading: Homework assignments and final test.

7 Information theoretic Methods in Security

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

Aim: To provide the students with an information theoretic framework that will allow formal modeling, and understanding fundamental performance limits, in several security-related problems

Topics: Topics will be chosen, according to the students' interests from the following list:
Measuring information. Review of basic notions and results in information theory: entropy, equivocation, mutual information, channel capacity.

The Holy Grail of perfect secrecy. Shannon's cipher system. Perfect secrecy. Ideal secrecy. Practical secrecy. The guessing attack.

Secrecy without cryptography. The wiretap channel model. Rate-equivocation pairs. 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.

A different approach. Secrecy capacity from channel resolvability. Secret-key capacity from channel intrinsic randomness.

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

Secrets in a crowd. Information theoretic secrecy in a random network with random eavesdroppers. Secrecy graphs and large networks secrecy rates.

A cipher for free? Information theoretic security of random network coding.

Who's who? An information theoretic model for authentication in noisy channels. Signatures and fingerprinting.

Writing in sympathetic ink. Information theoretic models of steganography, watermarking and other information hiding techniques.

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

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

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

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

References:

[1] Y. Liang, H.V. Poor, and S. Shamai (Shitz), *Information Theoretic Security,* Now, 2007.

[2] M. Bloch, J. Barros, *Physical-Layer Security: from Information Theory to Security Engineering* Cambridge University Press, 2011.

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

Time table: Course of 20 hours (two lectures of two hours each per week). Class meets every Wednesday and Friday from 10:30 to 12:30, starting on Wednesday, October 2 and ending on Wednesday, November 6, 2011. Room DEI/G (3-rd floor, Dept. of Information Engineering, via Gradenigo Building).

Course requirements: Basic notions of Information Theory

Examination and grading: Each student must submit a project, and grading will be based on its evaluation. I encourage students to work from an information theoretic point of view on a security problem related to their research activities.

8 Introduction to Quantum Optics: Quantum Information and Communication

Instructors: Paolo Villoresi, e-mail: `paolo.villoresi@unipd.it` and Giuseppe Vallone, email: `vallone@dei.unipd.it`

Aim: The Course is intended to provide the basic concepts of Quantum Information and Quantum Communications. It will start with review of the underlying concepts of quantum physics. It will be followed by the discussion of entanglement, quantum interference, quantum computation, and quantum communication. Specifics of practical implementation of quantum bits and quantum logic gates in different physical environments will be considered. Existing problems of experimental implementation associated with detrimental effects of decoherence will be discussed. The second part of this course is intended to provide the overview of novel technological approaches based on the use of quantum correlations and quantum entanglement. Specifics of optical implementation of qubits and linear-optical quantum gates will be discussed. This course will review specific concepts of quantum-optical state engineering and design of non-traditional quantum measurement devices that outperform their classical counterparts. Several such novel approaches as quantum imaging, super-resolution quantum phase measurement, dispersion cancelation, and correlated imaging and microscopy will be discussed.

The Course in organized in the Framework of the "Progetto Strategico di Ateneo" *QuantumFuture*.

Topics:

1. Review of Quantum Mechanics;
2. quantization of EM field;
3. statistics of radiation;
4. entanglement: definition and measure;
5. quantum interferometry;
6. principles of quantum computation and quantum key distribution.
7. Generation and tomography of entangled states;
8. linear-optical quantum state engineering;
9. teleportation and entanglement swapping
10. integrated quantum optics: example of quantum algorithm
11. Propagation of single photon beam along long channels and toward the Space.
12. Quantum Communications in Space.

References:

C. Gerry, P. Knight, "Introductory Quantum Optics", (Cambridge 2005)

Michel Le Bellac, "A Short Introduction to Quantum Information and Quantum Computation", (Cambridge 2006)

Additional reading:

A. V. Sergienko ed. "Quantum Communications and Cryptography", (CRC Press, Taylor & Francis Group 2006).

G. S. Jaeger, "Quantum Information: An Overview", Springer (2010).

Time table: Course of 28 hours (two lectures of two hours each per week). Class meets every Wednesday and Thursday from 2:30 to 4:30. First lecture on Wednesday, January 16th, 2013. There will be no lectures on February 6-th and 7-th (last lecture on March 7-th). Room 318 DEI/G (3-rd floor, Dept. of Information Engineering, via Gradenigo 6).

Course requirements: Basic concept of Quantum Physics.

Examination and grading: Homework and final exam.

9 Mathematical modeling of cell Biology

Instructor: Morten Gram Pedersen, Department of Information Engineering, University of Padova, e-mail: `pedersen@dei.unipd.it`

Aim: The aim of this course is to provide an introduction to commonly used mathematical models of cellular biology. At the end of the course, the students should be able to build models of biological processes within the cell, to simulate and analyze them, and to relate the results back to biology. The focus will be on electrical activity and calcium dynamics in neurons and hormone-secreting cells.

Topics: Biochemical reactions; Ion channels, excitablity and electrical activity; Calcium dynamics; Intercellular communication; Spatial and stochastic phenomena (if time allows); Qualitative analysis of nonlinear differential equations.

References: The following books will provide the core material, which will be supplemented by research articles:

[1] C.P. Fall, E.S. Marland, J.M. Wagner, J.J. Tyson. *Computational Cell Biology*. Springer, NY, USA (2002).

[2] J. Keener, J. Sneyd: *Mathematical Physiology*. Springer, NY, USA (2004).

Time table: Course of 20 hours (2 two-hours lectures per week). Class meets every Tuesday and Thursday from 1:30 to 3:30. First lecture on Tuesday, October 22, 2013. Room DEI/G (3-rd floor, Dept. of Information Engineering, via Gradenigo Building).

Course requirements: Basic courses of linear algebra and ODEs. Basic experience with computer programming. Knowledge of cellular biology is not required.

Examination and grading: Homeworks and/or final project.

10 Online algorithms and competitive analysis

Instructor: Enoch Peserico, e-mail: `online.algorithms.2013@gmail.com`

Aim: *An introduction to online algorithms and competitive analysis.*
An online problem is one where at least a partial solution must be produced before the entire input can be processed. A classic example would be to choose whether to accept or decline job offers as they are received: while ideally one would like to see all offers before choosing the "best", in practice one must choose to accept or decline an offer when it is received, without knowledge of future ones. Since an online algorithm does not know the whole input, it is forced to make decisions that may later turn out to be suboptimal. The study of online algorithms focuses on the quality of decision-making that is possible in this setting; competitive analysis formalizes this idea by comparing the relative performance of an online algorithm to the performance obtainable if one had complete knowledge of the input.

Topics (tentative list):

1. Introduction: renting skis and dealing with hangovers.
2. Randomized algorithms and adversaries: paging, web caching, and slot machines.
3. Dynamic data structures: online management of lists and trees.
4. Generalizations: the $k-$server problem and metric task systems.
5. Refinements and practical considerations: paging revisited and the stock market.
6. Ties to other fields: game theory, control theory and operations research.

References:

[1] Allan Borodin, Ran El-Yaniv: *Online Algorithms and Competitive Analysis*, Cambridge University Press, 1999.

[2] Selected articles from the literature.

Time table: Course of 20 hours. Class meets every Tuesday and Thursday from 10 to 12. First lecture on Tuesday, April 9th, 2013. Room 318 DEI/G (3-rd floor, Dept. of Information Engineering, via Gradenigo 6).

Course requirements: The course assumes basic grounding in algorithms and their analysis (one undergraduate course in algorithms and data structures is sufficient).

Examination and grading: Students will be required to form research groups of two or three people; to conduct research on a topic of their choice (ideally related to their doctoral research) in the field of online algorithms; and to present their results in a paper to be submitted to an online algorithms conference or workshop. Grading will be based on the research paper (80%) and on class participation (20%).

11 Physical models for the numerical simulation of semiconductor devices

Instructor: Prof. Giovanni Verzellesi, Dipartimento di Scienze e Metodi dellIngegneria, University of Modena and Reggio Emilia.
e-mail: `giovanni.verzellesi@unimore.it`
web: `http://www.dismi.unimore.it/index.php?q=verzellesi`

Aim: This course is intended to provide an introductory coverage on charge transport in semiconductors and on the physical models adopted in numerical device simulators, which are nowadays routinely adopted for the design and optimization of device fabrication processes (Technology Computer Aided Design or TCAD).

Topics: The course will cover the following topics:

a) Fundamentals of quantum mechanics and semiconductor physics: Schrdinger equation, Ehrenfest theorem, wavepackets, crystals, electrons in periodic structures, scattering mechanisms.

b) Charge transport in semiconductors: Boltzmann transport equation, momentum method, hydrodynamic model, drift-diffusion model, drift-diffusion model for non-uniform semiconductors, models for simulation of nano-scale devices.

c) Numerical device simulation: technology CAD, input and output data of device simulators, discretization of drift-diffusion equations, boundary conditions, physical models (mobility, generation-recombination effects, deep levels).

References: M. Lundstrom, *Fundamentals of carrier transport*, Modular Series on Solid State Devices vol. X, Addison-Wesley Publ. Company, ISBN 0-201-18436-2, 1992. K. Hess, *Advanced theory of semiconductor devices*, IEEE Press, ISBN 0-7803-3479-5, 2000. D. Vasileska, S.M. Goodnick, G. Klimeck, *Computational electronics: semiclassical and quantum device modeling and simulation*, CRC Press, ISBN 978-1420064834, 2010.

Time table: Course of 20 hrs (2 two-hour lectures per week). Class meets on Thursday 4:00 – 6:00 and Friday 10:00 – 12:00. Room DEI/G (3-rd floor, Dept. of Information Engineering, via Gradenigo Building).

Course requirements: Background at a graduate level on semiconductor devices.

Examination and grading: Final written test.

12 Power Converters in Renewable Energy Systems and Intelligent Microgrids

Instructor: Paolo Mattavelli, e-mail: paolo.mattavelli@unipd.it

Aim: The increasing number of renewable energy sources and energy storage devices connected to the grid has the potential to progressively increase the network performance in terms of efficiency, stability and demand response, while allowing full exploitation of any kind of Distributed Energy Resources (DERs). For this purpose the electronic power processors (EPPs) interfacing the power sources o storage elements with the distribution grid must be driven properly, controlling their active and reactive currents and harmonic distortion so as to improve power sharing, voltage stability and distribution losses. This course is aimed to give the fundamental knowledge of electronic power processors used in Distributed Energy Resources in future microgrids, including the main power converter topologies (including multilevel converters), modulation strategies, synchronization techniques and control for grid-connected and islanded operation.

Topics: Major topics of this course can be summarize as:

1. Power Converter topologies
2. Modulation strategies for 3-level inverter and Modular Multilevel Converter (MMC)
3. Inner current and voltage control of EPPs
4. Phase-Looked Loop for EPPs
5. Control techniques in islanded operation
6. Interaction and stability in ac microgrids

References: A set of lecture notes and corresponding references will be posted on the web site of this course.

Time table: Course of 20 hours. Class meets every Monday and Wednesday from 2:30 to 4:30. First lecture on Monday, September 30, 2013. Room DEI/G (3-rd floor, Dept. of Information Engineering, via Gradenigo Building).

Course requirements: Basic Knowledge of Power Electronics

Examination and grading: Homeworks and/or final examination.

13 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: 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.
- Analysis of a real-time control system for nuclear fusion experiment.

References:

[1] I C Bertolotti, G Manduchi. Real-Time Embedded Systems. Open Source Operating Systems Perspective. CRC Press, 2012

[2] G C Buttazzo. Hard Real-Time Computing Systems. Predictable Scheduling Algorithms and Applications. Springer 2005.

Time table: Course of 20 hours. Class meets every Tuesday and Thursday from 8:30 to 10:30. First lecture on Tuesday, February 19, 2013. Room DEI/G (3-rd floor, Dept. of Information Engineering, via Gradenigo Building).

Course requirements: Basic knowledge of Operating System concepts.

Examination and grading: Each student will develop a survey report based on one or several articles related to the material covered in class and referring to some field of application for real-time systems.

14 Resonant Converters and Inverters: Topologies and Modeling

Aim: the increased demand for more efficient and compact power supplies for a variety of applications together with the availability of faster switching devices, has pushed the switching frequency of modern power supplies from tens of kilohertz toward the megaherz range. At such frequency values, the corresponding switching losses become unacceptable and soft-commutations become mandatory. In this contest, resonant converter and inverter topologies have been rediscovered as valid alternative to classical PWM topologies. The aim of this course is to provide basic knowledge of resonant converter topologies, their operation as well as their modeling and control, together with suggestions on the best design procedures for different applications.

Topics:

1. Switching losses in Pulse Width Modulated converters
2. Basic dc-dc resonant converter topologies
   a. state-plane analysis;
   b. fundamental component analysis.
3. LLC resonant converter
4. Bidirectional resonant converters (Dual Active Bridge)
5. LCC resonant inverter for fluorescent lamps
6. Modeling of resonant converters and inverters

References: Lecture notes and written material on specific topics will be available.

Time table: Course of 20 hours. Class meets every Tuesday and Friday from 10:30 to 12:30. First lecture on Tuesday, May 28, 2013. Room DEI/G (3-rd floor, Dept. of Information Engineering, via Gradenigo Building).

Course requirements: Basic knowledge of Power Electronics.

Examination and grading: Homeworks and/or final examination.

15 Statistical Methods

Instructor: Lorenzo Finesso, Istituto di Ingegneria Biomedica, ISIB-CNR, Padova
e-mail: `lorenzo.finesso@isib.cnr.it`

Aim: The course will present a survey of statistical techniques which are important 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 informational divergence (Kullback-Leibler distance) of probability measures. The analytical and geometrical properties of the divergence will be presented.

Divergence minimization problems. Three basic minimization problems will be posed and, on simple examples, it will be shown that they produce the main methods of statistical inference: hypothesis testing, maximum likelihood, maximum entropy.

Multivariate analysis methods. Study of the probabilistic and statistical aspects of the three main methods: Principal Component Analysis (PCA), Canonical Correlations (CC) and Factor Analysis (FA). In the spirit of the course these methods will be derived also via divergence minimization. Time permitting there will be a short introduction to the Nonnegative Matrix Factorization method as an alternative to PCA to deal with problems with positivity constraints.

EM methods. The Expectation-Maximization method was introduced as an algorithm for the computation of the Maximum Likelihood (ML) estimator with partial observations (incomplete data). We will derive the EM method for the classic mixture decomposition problem and also interpret it as an alternating divergence minimization algorithm *à la* Csiszár Tusnády.

Hidden Markov models. We will introduce the simple yet powerful class of Hidden Markov models (HMM) and discuss parameter estimation for HMMs via the EM method.

The MDL method. The Minimum Description Length method of Rissanen will be presented as a general tool for model complexity estimation.

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

Time table: Course of 24 hours (two lectures of two hours each, per week). Class meets every Monday and Wednesday from 10:30 to 12:30. First lecture on Monday, June 17, 2013. Room DEI/G (3-rd floor, Dept. of Information Engineering, via Gradenigo Building).

Course requirements: Basics of Probability Theory and Linear Algebra.

Examination and grading: homework assignments and take-home exam.

16 Subspace Techniques for the Identification of Linear Systems

Instructor: Giorgio Picci, e-mail: `picci@dei.unipd.it`

Aim: To illustrate the basic principles and the main techniques available for subspace identification of linear multivariable systems.
Traditional parameter-optimization-based methods (such as Prediction Error Methods) are difficult to apply to multivariable system identification due to the need of canonical parametrizations and may lead to unreliable results because of local minima and bad conditioning. Subspace methods have been demonstrated to be a robust and reliable alternative to optimization-based algorithms. The theoretical foundation of subspace methods lay in stochastic realization theory and the algorithms are based on modern numerical linear algebra. The computational effort required by subspace identification algorithms is generally lower and the implementation is much easier. Experimental evidence shows also that the accuracy of subspace methods is generally comparable to that of the optimization-based procedures. They can in any case be used as a preliminary step to get reliable initial estimates for iterative optimization rutines. Statistical analysis of subspace methods is still not completely developed. This course aims also to provide a pointer to this research area.

Topics:

1. LINEAR STOCHASTIC STATE-SPACE MODELS: basic facts, the state process, minimality, Lyapunov equations for the state covariance, innovation representation, forward and backward representations, the forward and backward Kalman filter

2. STOCHASTIC REALIZATION AND THE LMI: rational spectral factorization, minimal spectral factors and the Linear Matrix Inequality, relation with Riccati equations and Kalman filtering.

3. HANKEL MATRICES AND REALIZATION BY CANONICAL CORRELATION ANALYSIS (CCA): CCA for random vectors, the Singular Value Decomposition (SVD), singular values of a linear systems, partial realization via Ho-Kalman, Positivity issues.

4. SUBSPACE IDENTIFICATION OF TIME SERIES: Basic ideas, dealing with finite data: finite interval stochastic realization, Hankel matrices from sample covariances and their approximate factorization, estimating $A, C, \bar{C}$ by solving the shift-invariance equations, estimating the B, D parameters, numerical aspects: the LQ decomposition.

5. EXOGENOUS SIGNALS AND FEEDBACK MODELS: stochastic state-space models wit inputs, joint innovation models, identifiability, abstract state space construction (oblique splitting), state space construction with feedback.

6. SUBSPACE IDENTIFICATION WITH INPUTS: Basic principles, the problem of finite data, finite-interval realization, the N4SID procedure, MOESP, consistency and ill-conditioning, asymptotic variance expressions, identification with feedback, the predictor model, description of various algorithms.

References:

[1] Chiuso, A. and G. Picci (2004). On the ill-conditioning of subspace identification with inputs. *Automatica*, **40**, 575-589.

[2] A. Chiuso and G. Picci (2005), "Consistency Analysis of some Closed-loop Subspace Identification Methods", *Automatica: special issue on System Identification*, **41** pp. 377-391.

[3] T. Katayama (2005) *Subspace Methods for System Identification*, Springer Verlag

[4] A. Lindquist and G. Picci, Canonical Correlation Analysis, Approximate Covariance Extension and Identification of Stationary Time Series, *Automatica*, **32** (1996), 709-733.

[5] J. Qin, L. Ljung (2003) "Closed-Loop Subspace Identification with Innovation Estimation", in *Proc. of the IFAC Int. Symposium on System Identification (SYSID)*, Rotterdam, 2003.

[6] P. van Overschee and B. De Moor, *Subspace algorithms for stochastic identification problem*, Automatica **3** (1993), 649-660.

[7] Overschee, P. Van and B. De Moor (1994). N4SID: Subspace algorithms for the identification of combined deterministic– stochastic systems. *Automatica* **30**, 75–93.

[8] Overschee, P. Van and B. De Moor (1996). *Subspace Identification for Linear Systems*, Kluwer Academic Pub.

Time table: Course of 20 hours. Class meets every Tuesday and and Thursday from 10:30 to 12:30. First lecture on Tuesday, March 5, 2013. Room DEI/G (3-rd floor, Dept. of Information Engineering, via Gradenigo Building).

Course requirements: Background on Linear systems and second order Random Processes.

Examination and grading: Homework + final exam.

17 Tissue Engineering: Principles and Applications

Instructor: Andrea Bagno, Department of Chemical Process Engineering (DPCI), 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.
3. Biomimetic materials.
4. Regeneration templates.
5. TE of biological tissues (cartilage, hearth valves, bone).

References:

[1] B. Palsson, J.A. Hubbel, R. Plonsey, J.D. Bronzino (Eds). Tissue engineering. CRC Press, Boca Raton, 2003.

[2] K.C. Dee, D.A. Puleo, R. Bizios. An introduction to tissue-biomaterials interactions. Wiley, Hoboken, New Jersey, 2002.

[3] J.B. Park, J.D. Bronzino, Biomaterials. CRC Press, Boca Raton, 2003.

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

Time table: Course of 12 hours (2 two-hours lectures per week). Class meets on on Monday and Wednesday, from 10:30 to 12:30. First lecture on January 21, 2013. Room DEI/G (3-rd floor, Dept. of Information Engineering, via Gradenigo Building).

Course requirements: Basic courses of chemistry, biology and physiology, biomaterials.

Examination and grading: Homework assignments and final test.

18 Topics in Quantum Information

Instructor: Francesco Ticozzi [ticozzi@dei.unipd.it]

Aim: The Course aims to serve as an introduction to a selection of topics of interest in quantum information theory, with a focus on the role of uncertainty and noise. A mathematically consistent approach will be developed, in order to tackle problems of information encoding, communication and error-correction for finite-dimensional systems.

Topics:

1. **Quantum Theory as a Probability Theory;** Densities, observable quantities, measurements in a non-commutative setting. Unitary dynamics. Composite systems and entanglement. Partial trace and marginal densities.

2. **Quantum Information Distances, Uncertainty and Distinguishability;** Entropy, relative entropy, trace norm, their interpretation and basic properties. Fidelity and related quantities.

3. **Quantum Dynamical Systems and Noise;** Open quantum systems and quantum operations. Kraus representation theorem. Errors and Markov noise models. Examples for two-level systems.

4. **Encoding Information in Quantum Systems;** The logical qubit. Encoding qubits in physical systems, operational requirements and "good codes".

5. **Classical and Quantum Information over Quantum Channels;** No-cloning theorem. Schumacher's quantum noiseless coding theorem. The Holevo-Schumacher-Westmoreland theorem.

6. **Advanced topics;** To be selected, depending on the research focus and interests of the attending students.

References: The main reference is M. A. Nielsen and I. L. Chuang, Quantum Computation and Quantum information (Cambridge, 2000). Other relevant references, on-line notes and research papers will be provided during the course.

Time table: Course of 16 hours. Class meets every Wednesday and Friday from 10:30 to 12:30. First lecture on Wednesday, February 20, 2013. Room DEI/G (3-rd floor, Dept. of Information Engineering, via Gradenigo Building).

Course requirements: Standard linear algebra and probability theory.

Examination and grading: Homeworks and final project.

January 2013

Ph.D. Courses: Room DEI/G

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
31	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16 2:30 PM Villoresi and Vallone	17 2:30 PM Villoresi and Vallone	18	19	20
21 10:30 AM Bagno	22	23 10:30 AM Bagno 2:30 PM Villoresi and Vallone	24 2:30 PM Villoresi and Vallone	25	26	27
28 10:30 AM Bagno	29	30 10:30 AM Bagno 2:30 PM Villoresi and Vallone	31 2:30 PM Villoresi and Vallone	1	2	3

February 2013

Ph.D. Courses: Room DEI/G

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
28 10:30 AM Bagno	29	30 10:30 AM Bagno 2:30 PM Villoresi and Vallone	31 2:30 PM Villoresi and Vallone	1	2	3
4 10:30 AM Bagno	5	6 10:30 AM Bagno	7	8	9	10
11	12	13 2:30 PM Villoresi and Vallone	14 2:30 PM Villoresi and Vallone	15	16	17
18 2:30 PM Maresca	19 8:30 AM Manduchi 2:30 PM Maresca	20 10:30 AM Tocozzi 2:30 PM Villoresi and Vallone	21 8:30 AM Manduchi 2:30 PM Villoresi and Vallone	22 10:30 AM Tocozzi	23	24
25 2:30 PM Maresca	26 8:30 AM Manduchi 2:30 PM Maresca	27 10:30 AM Tocozzi 2:30 PM Villoresi and Vallone	28 8:30 AM Manduchi 2:30 PM Villoresi and Vallone	1 10:30 AM Tocozzi	2	3

March 2013

Ph.D. Courses: Room DEI/G

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
25 2:30 PM Maresca	26 8:30 AM Manduchi 2:30 PM Maresca	27 10:30 AM Tocozzi 2:30 PM Villoresi and Vallone	28 8:30 AM Manduchi 2:30 PM Villoresi and Vallone	1 10:30 AM Tocozzi	2	3
4 2:30 PM Maresca	5 8:30 AM Manduchi 10:30 AM Picci 2:30 PM Maresca	6 10:30 AM Tocozzi 2:30 PM Villoresi and Vallone	7 8:30 AM Manduchi 10:30 AM Picci 2:30 PM Villoresi and Vallone	8 10:30 AM Tocozzi	9	10
11 2:30 PM Maresca	12 8:30 AM Manduchi 10:30 AM Picci 2:30 PM Maresca	13 10:30 AM Tocozzi	14 8:30 AM Manduchi 10:30 AM Picci	15 10:30 AM Tocozzi	16	17
18 2:30 PM Maresca	19 8:30 AM Manduchi 10:30 AM Picci 2:30 PM Maresca	20	21 8:30 AM Manduchi 10:30 AM Picci	22	23	24
25	26 10:30 AM Picci	27	28 10:30 AM Picci	29	30	31

April 2013

Ph.D. Courses: Room DEI/G

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
1	2 10:30 AM Picci	3	4 10:30 AM Picci	5	6	7
8	9 10:00 AM Peserico 2:30 PM Wimmer (Room Pe)	10	11 10:00 AM Peserico 2:30 PM Wimmer (Room Pe)	12	13	14
15	16 10:00 AM Peserico 2:30 PM Wimmer (Room Pe)	17	18 10:00 AM Peserico 2:30 PM Wimmer (Room Pe)	19	20	21
22	23 10:00 AM Peserico 2:30 PM Wimmer (Room Pe)	24	25 Holiday	26	27	28
29	30 10:00 AM Peserico 2:30 PM Wimmer (Room Pe)	1 Holiday	2 10:00 AM Peserico 2:30 PM Wimmer (Room Pe)	3	4	5

May 2013

Ph.D. Courses: Room DEI/G

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
29	30 10:00 AM Peserico 2:30 PM Wimmer (Room Pe)	1 Holiday	2 10:00 AM Peserico 2:30 PM Wimmer (Room Pe)	3	4	5
6	7 10:00 AM Peserico 2:30 PM Wimmer (Room Pe)	8 2:30 PM Someda	9 10:00 AM Peserico 2:30 PM Someda	10	11	12
13	14 10:00 AM Peserico	15 2:30 PM Someda	16 2:30 PM Someda	17	18	19
20	21	22 2:30 PM Someda	23 2:30 PM Someda	24	25	26
27	28 10:30 AM Spiazzi	29 2:30 PM Someda	30 2:30 PM Someda	31 10:30 AM Spiazzi	1	2 Holiday

June 2013

Ph.D. Courses: Room DEI/G

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
27	28 10:30 AM Spiazzi	29 2:30 PM Someda	30 2:30 PM Someda	31 10:30 AM Spiazzi	1	2 Holiday
3	4 10:30 AM Spiazzi	5 2:30 PM Someda	6 2:30 PM Someda	7 10:30 AM Spiazzi	8	9
10	11 10:30 AM Spiazzi	12	13 Holiday	14 10:30 AM Spiazzi	15	16
17 10:30 AM Finesso	18 10:30 AM Spiazzi	19 10:30 AM Finesso	20	21 10:30 AM Spiazzi	22	23
24 10:30 AM Finesso	25 10:30 AM Spiazzi	26 10:30 AM Finesso	27	28 10:30 AM Spiazzi	29	30

July 2013

Ph.D. Courses: Room DEI/G

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
1 10:30 AM Finesso	2	3 10:30 AM Finesso	4	5	6	7
8 10:30 AM Finesso	9	10 10:30 AM Finesso	11	12	13	14
15 10:30 AM Finesso	16	17 10:30 AM Finesso	18	19	20	21
22 10:30 AM Finesso	23	24 10:30 AM Finesso	25	26	27	28
29	30	31	1	2	3	4

August 2013

Ph.D. Courses: Room DEI/G

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
29	30	31	1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	1

September 2013

Ph.D. Courses: Room DEI/G

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
26	27	28	29	30	31	1
2	3 2:30 PM Pavon	4	5 2:30 PM Pavon	6	7	8
9	10 2:30 PM Pavon	11	12 2:30 PM Pavon	13	14	15
16	17 10:30 AM Pillonetto 2:30 PM Pavon	18	19 10:30 AM Pillonetto 2:30 PM Pavon	20	21	22
23	24 10:30 AM Pillonetto 2:30 PM Pavon	25	26 10:30 AM Pillonetto 2:30 PM Pavon	27	28	29
30 2:30 PM Mattavelli	1 10:30 AM Pillonetto 2:30 PM Pavon	2 8:30 AM Susin 10:30 AM Laurenti 2:30 PM Mattavelli	3 10:30 AM Pillonetto 2:30 PM Pavon	4 10:30 AM Laurenti	5	6

October 2013

Ph.D. Courses: Room DEI/G

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
30 2:30 PM Mattavelli	1 10:30 AM Pillonetto 2:30 PM Pavon	2 8:30 AM Susin 10:30 AM Laurenti 2:30 PM Mattavelli	3 10:30 AM Pillonetto 2:30 PM Pavon	4 10:30 AM Laurenti	5	6
7 2:30 PM Mattavelli	8 10:30 AM Pillonetto	9 8:30 AM Susin 10:30 AM Laurenti 2:30 PM Mattavelli	10 10:30 AM Pillonetto	11 10:30 AM Laurenti	12	13
14 2:30 PM Mattavelli	15 10:30 AM Pillonetto	16 8:30 AM Susin 10:30 AM Laurenti 2:30 PM Mattavelli	17 10:30 AM Pillonetto	18 10:30 AM Laurenti	19	20
21 2:30 PM Mattavelli	22 10:30 AM Pillonetto 1:30 PM Pedersen	23 8:30 AM Susin 10:30 AM Laurenti 2:30 PM Mattavelli	24 10:30 AM Pillonetto 1:30 PM Pedersen	25 10:30 AM Laurenti	26	27
28 2:30 PM Mattavelli	29 10:30 AM Pillonetto 1:30 PM Pedersen	30 8:30 AM Susin 10:30 AM Laurenti 2:30 PM Mattavelli	31 10:30 AM Pillonetto 1:30 PM Pedersen	1 Holiday	2	3

November 2013

Ph.D. Courses: Room DEI/G

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
28 2:30 PM Mattavelli	29 10:30 AM Pillonetto 1:30 PM Pedersen	30 8:30 AM Susin 10:30 AM Laurenti 2:30 PM Mattavelli	31 10:30 AM Pillonetto 1:30 PM Pedersen	1 Holiday	2	3
4	5 1:30 PM Pedersen	6 8:30 AM Susin 10:30 AM Laurenti	7 1:30 PM Pedersen 4:00 PM Verzellesi	8 10:00 AM Verzellesi	9	10
11	12 1:30 PM Pedersen	13	14 1:30 PM Pedersen 4:00 PM Verzellesi	15 10:00 AM Verzellesi	16	17
18	19 1:30 PM Pedersen	20	21 1:30 PM Pedersen 4:00 PM Verzellesi	22 10:00 AM Verzellesi	23	24
25	26	27	28 4:00 PM Verzellesi	29 10:00 AM Verzellesi	30	1

December 2013

Ph.D. Courses: Room DEI/G

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
25	26	27	28 4:00 PM Verzellesi	29 10:00 AM Verzellesi	30	1
2	3	4	5 4:00 PM Verzellesi	6 10:00 AM Verzellesi	7	8 Holiday
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31	1	2	3	4	5