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

Course Catalogue

2009

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* two 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 third course is *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. *Fourier transform and convolution*: The convolution product and its properties. The basic L^1 and L^2 theory of the Fourier transform. The inversion theorem.

4. *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.

5. *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. Support vector regression and regularization networks. 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] E. Kreyszig, Introductory Functional Analysis with Applications, John Wiley and Sons , 1978.

[2] M. Reed and B. Simon, Methods of Modern Mathematical Physics, vol. I, Functional Analysis, Academic Press, 1980.

[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.

Time table: Course of 28 hours (2 two-hours lectures per week): Classes on Monday and Thursday, 10:30 - 12:30. First lecture on Monday, September 14, 2009. 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

Instructors:

Tobias Damm, TU Kaiserslautern, Germany
e-mail: `damm@mathematik.uni-kl.de`

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

Aim: We study concepts and techniques of linear algebra, which 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:

- *Matrix equations and inequalities*
- *Kronecker products and structured matrices*
- *Least squares problems and singular value decomposition*
- *Computational methods*
- *Perturbation theory*

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.

[4] L. N. Trefethen and D. Bau *Numerical Linear Algebra*. SIAM, Philadelphia, 2000.

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

Time table: Course of 16 hours (2 two-hours lectures per week): Classes on Tuesday and Thursday, 4:30 – 6:30 P.M. First lecture on Tuesday, March 17, 2009. Classroom Oe (Dept. of Information Engineering, via Gradenigo Building).

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

3 Bioelectromagnetics

Instructor: Prof. Tullio A. Minelli, CIRMANMEC University of Padova, e-mail: minelli@pd.infn.it.

Aim: Comprehension of bio-physics and bio-mathematical instruments underlying cell and tissue electromagnetic stimulation. A phenomena survey.

Topics:

1. Basics of bioelectromagnetics.
2. Neuroelectrical phenomena.
3. Chaos, fractals, solitons and neuroelectrical signals.
4. Mobile phone radiation and neuroelectrical phenomena.
5. Neurodegeneration: Bio-physical and bio-mathematical phenomenology.
6. Mathematical models of cell membrane dynamics.

References:

[1] C. Polk and E. Postow. CRC handbook of biological effects of electromagnetic fields. Boca Raton, CRC Press 1986.

[2] C.H. Durney and D.A. Christensen. Basic introduction to bioelectromagnetics. Boca Raton, CRC Press, 2000.

[3] S. Deutsch and A. Deutsch. Understanding the nervous system. An Engineering perspective. New York: IEEE, 1993.

[4] S.S. Nagarajan. A generalized cable equation for magnetic stimulation of axons. IEEE Transactions on biomedical Engineering, 43, 304-312, 1996.

[5] M. Balduzzo, F. Ferro Milone, T.A. Minelli, I. Pittaro Cadore and L. Turicchia: Mathematical phenomenology of neural synchronization by periodic fields, Nonlinear Dynamics, Psychology and Life Sciences 7, pp.115-137, 2003.

[6] A. Vulpiani. Determinismo e caos. La nuova Italia Scientifica, Roma, 1994.

[7] T.A. Minelli, M.Balduzzo, F. Ferro Milone and V.Nofrate: Modeling cell dynamics under mobile phone radiation. Nonlinear Dynamics, Psychology and Life Sciences, to appear.

[8] Report on the potential health risk of Radiofrequency Fields (the Royal Society of Canada, 2001-2003).

[9] C.P.Fall. Computational Cell Biology. Berlin, Springer, 2002.

[10] J.D. Murray. Mathematical Biology. Berlin: Springer-Verlag, 1993.

[11] Bioinitiative Report, 2007 in http://www.bioinitiative.org/report/index.htm

Time table: Course of 12 hours plus a visit to an electro-physiology laboratory. Lectures (2 hours) on Friday 11:00 – 13:00. First lecture on Friday, January 9, 2009. Room DEI/G (3-rd floor, Dept. of Information Engineering, via Gradenigo Building).

Course requirements: None.

Examination and grading: Production of simple pedagogical circuits or measures and simulations of biophysical interest.

4 Codes, graphical models, distributed algorithms

Instructor: Fabio Fagnani, e-mail: `fabio.fagnani@polito.it`

Aim: The goal of this course is twofold. We will first give a quick introduction to channel coding theory with a special emphasis on low density parity check codes and iterative decoding techniques which have been developed in the last 15 years and have allowed to concretely achieve the fundamental Shannon limit. Iterative decoding is an instance of the so-called Belief Propagation (BP) algorithm whose range of possible applications is much wider than just coding. In short, BP is a low-complexity algorithm which allows to compute (in an approximative way) the marginals of a stochastic process defined on a graph. BP can be applied to solve a variety of problems in artificial intelligence, statistical inference, estimation, combinatorics. In the second part of the course we will consider such more general instances of BP algorithm, we will establish some theoretical results and we will investigate some connections with statistical mechanics.

Topics:

1. [6h] Codes for reliable transmission over noisy digital channels. Maximum-a-posteriori (MAP) decoding. Shannon theorem. Some important channels: the binary symmetric channel (BSC), the binary erasure channel (BEC), the Gaussian channel. Complexity of a coding scheme. Linear binary codes, syndromes, minimum distances, weight enumerators, spectra, theoretical bounds. Examples of specific codes and ensembles of codes.

2. [6h] Graphical representations of codes, Tanner graphs. MAP inference for codes represented by tree-like graphs. The Belief Propagation (BP) algorithm. BP for graphs with cycles. Analysis for the case of the binary erasure channel (BEC). Low density parity check (LDPC) codes: regular and irregular ensembles. LDPC over the BEC: performance analysis using the density evolution technique, concentration analysis. The peeling algorithm. Extension to more general transmission channels. Digital fountain codes.

3. [8h] Probabilistic graphical models. The Hammersley-Clifford theorem. Distributed inference problems. BP on tree-like graphs and on graphs with cycles. The exactness of BP on Gaussian Markov fields and on graphs with a single loop. Other applications of BP: combinatorial problems on graphs (matchings, spanning trees, colorings). The connection with statistical mechanics: the Bethe free energy interpretation.

References:

- M. Bayati, C. Borgs, J. Chayes, R. Zecchina. Belief-Propagation for Weighted b-Matchings on Arbitrary Graphs and its Relation to Linear Programs with Integer Solutions. arXiv:0709.1190v2, 2008

- R. G. Gallager, Low Density Parity Check Codes, Cambridge, MA: MIT Press, 1963.

- B. Huang, T. Jebara, Loopy belief propagation for bipartite maximum weight b-matching, Artificial Intelligence and Statistics (AISTATS), March, 2007.

- C. C. Moallemi and B. Van Roy. Convergence of the min-sum message passing algorithm for quadratic optimization. Technical report, Management Science and Engineering Department, Stanford University, 2006.

- T. Richardson and R. Urbanke. The capacity of low-density parity check codes under message-passing decoding. IEEE Transactions on Information Theory, 47:599618, 2001.
- T. Richardson and R. Urbanke. Modern Coding Theory. Cambridge University Press, 2008.
- M. J. Wainwright, T. S. Jaakkola, and A. S. Willsky, Tree-based reparameterization framework for analysis of sumproduct and related algorithms, IEEE Trans. Inf. Theory, vol. 49, no. 5, pp. 11201146, May 2003.
- Y. Weiss, Correctness of local probability propagation in graphical models with loops, Neural Comput., Vol. 12, pp. 1-42, 2000.
- Y. Weiss and W. Freeman, Correctness of belief propagation in Gaussian graphical models of arbitrary topology, Neural Comput., Vol. 13, Issue 10, pp. 2173-2200, 2001.
- J. S.Yedidia, W. T. Freeman, and Y.Weiss, Understanding belief propagation and its generalizations, Mitsubishi Electric Research Labs, Tech. Rep. TR200122, Jan. 2002.

Time table: Course of 20 hours. Lectures (2 hours) on Tuesday and Thursday 4:30 – 6:30 P.M.. First lecture on Tuesday, April 21, 2009. Room DEI/G (3-rd floor, Dept. of Information Engineering, via Gradenigo Building).

Course requirements: Basic courses on calculus, linear algebra, probability.

Examination and grading: 5 weekly homeworks.

5 Computation of Game and Market Equilibria

Instructor: Dr. Bruno Codenotti, Research Director, Istituto di Informatica e Telematica, CNR Pisa, Italy. e-mail: `bruno.codenotti@iit.cnr.it`

Aim: The widespread use of Internet has promoted tighter interactions between Computer Science and Game Theory. Game Theory techniques are being increasingly used to analyze scenarios featuring users with potentially conflicting interests. In such environments, a fundamental notion is the one of *equilibrium*. The main purpose of this course is to analyze different notions of equilibrium under suitable models (non-cooperative games, cooperative games, and markets). Specifically, we will discuss the computation of such equilibria and their applications to relevant case studies (e.g., routing, resource sharing, pricing of shared resources, etc.).

Topics:

1. Non-cooperative games in normal form
   - Two-player constant-sum games
   - Two-player variable-sum games
   - Multi-player games
   - Existence of Nash equilibria
2. Cooperative Games
   - Cooperative three-player games
   - Bargaining
   - Cooperative multi-player games
   - Coalitions
   - Equilibria in a cooperative environment (core, kernel, nucleolus, Shapley value)
3. Markets
   - Simple market models
   - Arrow-Debreu model
   - Walras equilibrium (definition, existence results)
   - Markets and games: comparison and reductions
4. Classical Algorithms
   - Preliminaries: Sperner's lemma
   - Scarf's algorithm
   - Lemke-Howson's algorithm
   - Variations and extensions
5. Recent Algorithms and Applications
   - Selection of recent algorithms (chosen based on the students' interests and inclinations)

- Selfish routing: Nash equilibria vs optimal solution
- Resource sharing: fairness criteria
- Mechanism design and Internet protocols

References: The material for the class will be covered by excerpts from the following reference books.

- M.J. Osborne, A. Rubinstein. *A Course in Game Theory.* MIT Press, 2001.
- N. Nisan, T. Roughgarden, E. Tardos, V.V. Vazirani. *Algorithmic Game Theory.* Cambridge University Press, 2007
- W. Hildenbrand, H. Sonnenschein Eds. *Handbook of Mathematical Economics.* North Holland, 1991.
- G. Owen. *Game Theory.* Academic Press, 1982.
- A. Mas-Colell, M.D. Whinston, J. Green. *Microeconomic Theory.* Oxford Univ. Press, 1995.

Time table: Course of 20 hours. Lectures (2 hours) on Monday 2:30 – 4:30 P.M. and Tuesday 10:30 – 12:30. First lecture on Monday, March 9, 2009. Room DEI/G (3-rd floor, Dept. of Information Engineering, via Gradenigo Building).

Course requirements: Basic background in algorithms and mathematics.

Examination and grading: Each student is expected to give a presentation in the class on a topic previously agreed with the teacher. The presentation will be followed by a discussion with the teacher and the other students. The final grade will be based on the presentation and on the participation to class activities.

6 Design Patterns in Software Development

Instructor: Gabriele Manduchi, Istituto Gas Ionizzati del CNR
e-mail: gabriele.manduchi@igi.cnr.it

Aim: Introduction of Design Patterns in software development. The course is centered around a case study in software development in "e-Science". A graphical front-end for browsing and visualizing scientific data is progressively refactored using important design patterns for object-oriented software. The use of design patterns is presented in the context of the Unified Process. An introduction to UML and the Unified Process is presented at the beginning of the course.

Topics:

1. **Advanced Java Programming**: the case study refers to a graphical waveform browser for networked scientific data.
2. **Design Patterns definition**: design patterns are introduced step by step during the refactoring stages. Finally an overview of the most useful design patterns which have not been encountered in the case study is provided.
3. **UML Modelling**: a subset of UML will be used thorough the course to represent class organization and component relationships.
4. **Unified Process**: The steps in the case study are presented in the more general framework of theUnified Process, by first analyzing Use Cases and then introducing the basic architecture.

References:

1. E. Gamma, R. Helm, R. Jonson, J. Vlissides: Design Patterns: Elements of Reusable Object Oriented Software, Addison Wesley 1995
2. Henry Gardner, Gabriele Manduchi: Design Patterns for e-Science Springer, 2007.
3. John Hunt: Guide to the Unified Process, Springer 2003.

Time table: Course of 20 hours. Lectures (two hours) on Monday and Wednesday 8:30 – 10:30. First lecture on Monday, November 2, 2009. Room DEI/G (3-rd floor, Dept. of Information Engineering, via Gradenigo Building).

Course requirements: Basic Java programming, Object-Oriented terminology and methods.

Examination and grading: A project will be assigned to students, and will represent the base of the final discussion

7 Dose, effect, threshold

Instructor: Prof. Andrea Trevisan, Dipartimento di Medicina Ambientale e Sanità Pubblica, Univ. di Padova, e-mail: `andrea.trevisan@unipd.it`

Aim: understanding of biological mechanisms that are the basis of the effect of chemical, physical and biological agents in humans. To supply a critical evaluation of the reference data on biological effects of electromagnetic fields.

Topics: General introduction to cell biology and mechanisms of pharmacokinetics. The dose and the significance of threshold. The effect (response) of the dose. Methods to define the threshold. The significance of cancer and the threshold problem. Electromagnetic fields and general aspects related to the dose and the effect.

References: Handouts provided by the instructor.

Time table: Course of 12 hours. Lectures (2 hours) on Thursday 10:30 – 12:30. First lecture on Thursday, Jan. 8, 2008. Room DEI/G (3-rd floor, Dept. of Information Engineering, via Gradenigo Building).

Course requirements: None.

Examination and grading: Oral exam.

8 Dynamical Models in Systems Biology

Instructor: Claudio Altafini, SISSA (Int. School for Advanced Studies), Trieste.
e-mail: `altafini@sissa.it`

Aim: The course aims at providing an overview of some of the mathematical tools used in the modeling of biological phenomena. The emphasis is on nonlinear models and system analysis, and the examples are mostly from signaling and metabolic pathways.

Topics:

1. Qualititative analysis of ODE models
   - single and two-species dynamics
   - linear and nonlinear systems, equilibria and (multi)stability, monotonicity
   - oscillations
2. Examples of specific "biological mechanisms"
   - predator-prey models
   - epidemic models (HIV dynamics, kinetic of prion replication)
   - precision (kinetic proofreading)
   - adaptation (bacterial chemotaxis)
   - autoinduction (quorum sensing)
3. Whole network dynamical theories:
   - Stoichiometric network analysis
   - Metabolic control analysis
   - Chemical reaction network theory

References:

- L. Edelstein-Keshet. "Mathematical Models in Biology", SIAM Classics, 2005.
- E. Sontag, "Lecture Notes in Mathematical Biology", available at the URL: http://www.math.rutgers.edu/∼sontag/613.html
- U. Alon, "An Introduction to Systems Biology", CRC press, 2007.
- B. O. Palsson, "Systems Biology", Cambridge Univ. Press, 2006.
- E. Klipp, R. Herwig, A. Kowald, C. Wierling, H. Lerhach, "Systems Biology in Practice", Wiley, 2005.

Time table: Course of 16 hours. Lectures (two hours) on Monday and Wednesday 2:30 – 4:30 P.M. First lecture on Monday, February 2, 2009. Room DEI/G (3-rd floor, Dept. of Information Engineering, via Gradenigo Building).

Course requirements: Basic courses of linear algebra and ODEs.

Examination and grading: Final project and student seminar.

9 Identification techniques

Instructor: Professor Alessandro Chiuso, Dept. Tecnica e Gestione dei Sistemi Industriali, University of Padova, e-mail: `chiuso@dei.unipd.it`

Aim: This course is intended to provide a deep comprehension of modern method for identification of multivariable (MIMO) systems.

Topics:

1. BACKGROUND OF STATISTICS AND PARAMETER ESTIMATION (Brief Overview)

   Parametric estimation theory, properties of estimators: bias, consistency, variance.

   Parametric Estimators for Linear-Gaussian models. Model selection and validation.

2. LINEAR STOCHASTIC MODELS AND STOCHASTIC PROCESSES

   Second order description of stationary stochastic processes. Linear models (State Space, ARX, ARMAX). Stochastic Realization. Stochastic Feedback and causality. Feedback Models. Invariance of the feedback model. Parametric Models, Identifiability. Ergodic Processes.

3. REVIEW OF PARAMETRIC IDENTIFICATION FOR ARX, ARMAX MODELS AND STATE SPACE MODELS (Brief Overview).

   ML (Maximum Likelihood) and PEM (Prediction error methods) for multivariable ARX, ARMAX and SS models. Iterative Algorithms for the minimization of the mean quadratic error in general ARMAX models. Quasi-Newton method. Main complications: identifiability in multivariable models. Canonical forms, local minima, over-parameterization and ill-conditioning.
   State space models: Data Driven Local Coordinates and EM Based Approaches.

4. SUBSPACE IDENTIFICATION FOR MULTIVARIABLE STATE SPACE MODELS

   The "subspace" approach. State construction: from stochastic realization to algorithms. Role of the Singular Value decomposition. Main algorithms: CCA, N4SID and MOESP. Main numerical routines: SVD and QSVD. The positivity issue. Discussion of the routines available in the literature. Numerical comparison of different methods on simulated examples. Subspace Identification with feedback. Connections between Subspace Identification and ARX modeling.

5. ASYMPTOTIC STATISTICAL PROPERTIES OF SUBSPACE ESTIMATORS

   Consistency and Asymptotic Normality. Asymptotic variance expressions and their computation. Asymptotic Statistical Efficiency. Improving the estimators.

6. NON-PARAMETRIC METHODS FOR SYSTEM IDENTIFICATION

   Gaussian Processes and Reproducing Kernel Hilbert Spaces. Representer theorem and regularization networks. Gaussian processes for system identification. Choice of the kernel: empirical Bayes method.

7. COMPUTER SIMULATIONS AND CASE STUDIES

References: For the first part of the course references are:
1. T. Söderström, P. Stoica, *System Identification*, Prentice Hall 1989.
2. L. Ljung *System Identification, Theory for the user* (2^a ed).
3. A.W. van der Vaart *Asymptotic Statistics*, Cambridge University Press. 4. T. Ferguson, *A Course in Large Sample Theory*, Chapman and Hall, 1996.
5. G. Wahba. *Spline models for observational data*, SIAM, Philadelphia, 1990.

For the second part of the course the instructor will provide specific material (journal and conference papers, etc.).

Time table: Course of 20 hours (two two-hours lectures per week): Classes on Monday and Wednesday from 4:30 to 6:30 P.M., first lecture on Monday, April 20, 2009. Room DEI/G (3-rd floor, Dept. of Information Engineering, via Gradenigo Building).

Course requirements: Knowledge of probability theory, linear systems theory, stochastic systems, system identification and MATLAB/SIMULINK will be assumed.

Examination and grading: Homework assignments and final test on identification and validation of a model with data provided by instructor.

10 Introduction to Quantum Optics

Instructors: Paolo Villoresi and Cristian Bonato,
e-mail: paolo.villoresi@unipd.it, bonatocr@dei.unipd.it

Aim: The Course is intended to provide the basic concepts of current Quantum Communications in the optical domain. The initial part will review the underlying physical concepts, while in the second part the topics of entanglement, quantum interference, teleportation, quantum computation and quantum key distribution will be addressed. The experimental implementations of these topics will be discussed.

Topics:

1. Review of Quantum Mechanics;
2. quantization of EM field;
3. statistics of radiation;
4. entanglement;
5. quantum interferometry.
6. Applications: teleportation, quantum computation and quantum key distribution.

References: Gerry C, Knight P, Introductory Quantum Optics (Cambridge 2005)

Time table: Course of 20 hours. Lectures (2 hours) on Wednesday 2:30 – 4:30 P.M., and Friday 10:30 – 12:30. First lecture on Wednesday, March 4, 2009. Room DEI/G (3-rd floor, Dept. of Information Engineering, via Gradenigo Building).

Course requirements: Basic concept of Quantum Physics.

Examination and grading: Homework and final exam.

11 Nonlinear Feedback Systems

Instructor: Prof. Christopher I. Byrnes, Department of Electrical and Systems Engineering, Washington University in St. Louis. e-mail: chrisbyrnes@wustl.edu

Aim: Nonlinear feedback systems are pervasive in biology, control and communications. This course will teach methods for analyzing and designing nonlinear feedback systems. Particular applications will be to stability, stabilization and shaping the steady-state response of nonlinear control systems.

Topics:

1. Basic Nonlinear Analysis

- The inverse function theorem, the implicit function theorem, the contraction mapping principle
- One-dimensional nonlinear dynamical systems
- Population dynamics with constant harvesting
- The set-point control problem for nonlinear control systems

2. Basic Nonlinear Dynamics

- Properties of solutions of nonlinear ordinary differential equations
- The voltage controlled oscillator
- The Poincaré map
- Poincaré Bendixson Theorem

3. Stability of equilibria, periodic orbits and attractors

- Limit sets for initial conditons and initial sets
- Liapunov theory for invariant sets
- The set-point control problem for a nonlinear AC motor
- The existence and stability of periodic orbits
- The steady-state behavior of nonlinear systems

4. Stability of control systems

• Input-to-state systems

• The small gain theorem for nonlinear systems

• Zero dynamics and minimum phase systems

• Dissipative periodic processes

5. Shaping the response of a nonlinear control system

• The steady-state response of a nonlinear control system

• Output regulation

• Analysis and design of the steady-state behavior of nonlinear feedback systems

References: The course will be based on lecture notes and power point presentations that will be available on the course website. Other reference material would include:

H. Khalil, Nonlinear Systems, Prentice-Hall (for nonlinear dynamics)

A. Isidori, Nonlinear Control Systems, II, Springer-Verlag (for stability of control systems)

Time table: Course of 16 hours. Lectures (2 hours) on Tuesday 10:30 –12:30 and Thursday 2:30 – 4:30 P.M.. First lecture on Tuesday, January 13, 2009. Room DEI/G (3-rd floor, Dept. of Information Engineering, via Gradenigo Building).

Course requirements: It is expected that students have taken courses in classical automatic control and linear systems. We will present basic material from nonlinear analysis and nonlinear dynamical systems, along with examples.

Examination and grading: The grade for the class will be based on homework.

12 Physical models for the numerical simulation of semiconductor devices

Instructor: Prof. Giovanni Verzellesi, Department of Information Engineering, University of Modena and Reggio Emilia e-mail: `giovanni.verzellesi@unimore.it`, `http://www.dii.unimo.it/wiki/index.php/User:Verzellesi`

Aim: This course is intended to provide an introductory coverage on charge transport in semiconductors and on the physical models underlying the semiconductor 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. Doping. Scattering mechanisms.

b) Charge transport in semiconductors: Boltzmann transport equation. Momentum method. Hydrodynamic model. Drift-diffusion model. Drift-diffusion model for non-uniform semiconductors.

c) Numerical device simulation: Technology CAD. Input and output data for device simulation. Discretization of drift-diffusion equations. Boundary conditions.

d) Physical models: band-gap narrowing, incomplete ionization, carrier mobility, generation-recombination effects, deep levels.

References:

[1] M. Lundstrom, "Fundamentals of carrier transport", Modular Series on Solid State Devices vol. X, Addison-Wesley Publ. Company, ISBN 0-201-18436-2, 1992.

[2] K. Hess, "Advanced theory of semiconductor devices", IEEE Press, ISBN 0-7803-3479-5, 2000.

Time table: Course of 20 hours. Lectures (two hours) on Thursday 2:30 – 4:30 P.M., and Friday, 10:30 – 12:30. First lecture on Thursday, October 29, 2009. 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 test.

13 Pollution and Prevention

Instructor: Prof. Giovanni Battista Bartolucci, Department of Environmental Medicine and Public Health, Occupational Medicine - University of Padova.
e-mail: giovannibattista.bartolucci@unipd.it

Aim: Knowledge of legislation and prevention measures in the field of life and work environment; understanding of procedures for exposure and risk evaluation.

Topics: Principal laws for protection in life and work environment. Procedures for risk assessment and risk management. The evaluation of exposure. Air quality in life environment: the example of fine dusts and benzene. Principal chemical and physical risks in work environment: organic and inorganic dusts, fibres, metals, solvents, microclimate, noise, vibrations (methods of measure and health risks). The individual and collective prevention measures.

References: Handouts provided by the instructor.

Time table: Course of 12 hours (2 two-hours lectures per week): Classes on Tuesday and Thursday from 4:30 to 6:30 P.M.; first lecture on Tuesday January 27-th, 2009. Room DEI/G (3-rd floor, Department of Information Engineering, via Gradenigo Building).

Course requirements: None.

Examination and grading: Homework assignment and final examination.

14 Positron Emission Tomography (PET)

Instructor: Prof. Maria Carla Gilardi, University of Milano Bicocca,
e-mail: `mariacarla.gilardi@hsr.it`

Aim: The aim of the course is to provide a survey of technological issues and applications in Positron Emission Tomography (PET)

Topics:
1. State of the art PET systems.
2. Quantification issues in PET.
3. 4D PET and radiotherapy.

References:

[1] Bailey, D.L., Townsend, D.W., Valk, P.E., Maisey, M.N. (Eds.) Positron Emission Tomography, 2005.

[2] Muehllehner G et al. Positron emission tomography. 2006 Phys. Med. Biol. 51 R117-R137.

[3] Alessio A, Kinahan P, Cheng P, Vesselle H, Karp J PET/CT scanner instrumentation, challenges, and solutions. Radiologic Clinics of North America, 42 (6): 1017-103.

[4] Dawood M, Buther F, Lang N. Respiratory gating in positron emission tomography: a quantitative comparison of different gating schemes. 2007 Med Phys 34(7): 3067-3076.

[5] Endo M et al. Four-dimensional Computed Tomography (4D) concepts and preliminary development. 2003 Radiation medicine 21(1):17-22.

Time table: Course of 12 hours: Classes (2 hours) on: Wednesday, January 14, 10:30 – 12:30, Wednesday, January 21, 2:30 – 4:30 P.M., Wednesday, January 28, 2:30 – 4:30 P.M., Wednesday, February 4, 4:30 – 6:30 P.M., Monday, February 9, 4:30 – 6:30 P.M., Tuesday, February 10, 10:30 – 12:30. Room DEI/G (3-rd floor, Dept. of Information Engineering, via Gradenigo Building).

Course requirements: None.

Examination and grading: Grading will be based on a written examination

15 Real-Time Operating Systems

Instructor: Ivan Bertolotti Cibrario
e-mail: `ivan.cibrario@polito.it`

Aim: The course, first of all, summarizes the internal architecture of a real-time operating system. Then, after recalling the main issues concerning real-time concurrent programming, it describes in detail the main models, algorithms and techniques being used for both real-time scheduling and scheduling analysis. Furthermore, the course discusses how the synchronization and communication problems among real-time processes are dealt with, both by classical lock-based techniques, and by lock and wait-free synchronization.

Topics:

1. **Introduction to Real–Time Operating Systems**
   Definition, characteristics, classification and examples of real-time systems. Architecture of a real-time operating system: monolithic and layered systems, microkernel-based systems, virtual machines. System call and interrupt handling mechanisms. Memory and I/O device management.

2. **Concurrent Programming and Real-Time**
   Notion of process and thread. Concurrent execution and its issues: race conditions, deadlock, starvation. Classical IPC problems and their pitfalls revisited from the real-time point of view.

3. **Real-Time Scheduling Models and Algorithms**
   Scheduling models: cyclic executive, Rate Monotonic (RM), Deadline Monotonic (DM), and Earliest Deadline First (EDF) schedulers and their implementation techniques. Preemptive versus non-preemptive schemes. Scheduling of sporadic and aperiodic tasks (outline).

4. **Scheduling Analysis**
   Utilization-based schedulability tests for RMS and EDF (Liu and Layland). Response time analysis for fixed priority schedulers (full) and EDF (outline). Handling of sporadic and aperiodic processes (outline).

5. **Real-Time Scheduling and IPC** Modeling process interactions and blocking. The priority inversion problem and its solutions: priority inheritance, priority ceiling, and immediate priority ceiling protocols. Relationship between priority ceiling protocols and deadlock prevention algorithms. Extension of scheduling analysis to handle blocking

6. **Lock and Wait-Free Synchronization** Introduction to lock and wait-free synchronization techniques. Comparison between these techniques and the classic, semaphore-based synchronization techniques. Suitability and advantages of lock and wait-free synchronization for real-time execution. Implementation with and without hardware assistance.

7. **Execution Environment and Real-Time** Further extensions to the the scheduling model to consider non-negligible context switch times, interrupt handling, and the real-time clock handler. Effects of the CPU and system architectures on execution determinism and worst-case execution time analysis.

References:

[1] A. Burns, A. Wellings, *Real-Time Systems and Programming Languages*, 3rd edition, 2001, Pearson Education (formerly Addison Wesley)

[2] G. C. Buttazzo, *Hard real–time computing systems. Predictable scheduling algorithms and applications*, 2nd edition, 2005, Springer

Time table: Course of 16 hours. Lectures (two hours) on Wednesday from 2:30 to 4:30 P.M. and Thursday from 10:30 to 12:30. First lecture on Wednesday, April 22, 2009. Room DEI/G (3-rd floor, Dept. of Information Engineering, via Gradenigo Building).

Course requirements: General notions about computer architecture, theory and structure of general-purpose operating systems;

Examination and grading: Homework and/or Oral exam

16 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 Maximum Likelihood (ML) estimator with partial observations (incomplete data). We will present the EM method as an alternating divergence minimization algorithm (à la Csiszár Tusnády) and show its application to the ML estimation of Hidden Markov Models.

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 (2 two-hours lectures per week): Classes on Monday and Wednesday, 2:30 – 4:30 P.M. First lecture on Monday, November 9, 2009. 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.

17 Stochastic Modeling of Computer and Communication Systems

Instructor: Andreas Willig
e-mail: `awillig@tkn.tu-berlin.de`

Aim: This course aims to provide some of the mathematical techniques that are important for probabilistic performance analysis studies in computer- and communication systems. The focus is on Markov chains and queueing systems and their application in the performance analysis of communication protocols. The mathematical parts of the course aim to achieve a reasonable (for engineers) level of mathematical rigor.

Topics:

1. **Probability theory refresher**
2. **Discrete-time Markov chains**
   Definition and basic properties;
   Classification of states.
   Hitting Times, Stopping Times and Strong Markov
   Long-term behaviour of Markov chains, Steady-state solutions
   Protocol analysis examples
3. **Continuous-time Markov Chains**
   Matrix exponentials and Q-matrices
   Definition of CTMCs
   Classification of states, Hitting Probabilities
   Long-term behaviour, Steady-state
   Birth-Death and Pure-Birth processes
   Examples
4. **Renewal and Poisson processes**
   Definition of renewal processes
   Hidden and exposed terminal problems, solution considerations
   Residual Lifetimes
   Definition and equivalent characterizations of Poisson processes
5. **Queueing Theory**
   Introduction, Notation, Little's Law
   Markovian Systems
   M/G/1 systems
   Polling and priority systems

References:

Lecture Notes provided by the instructor:
Andreas Willig, *Stochastic Performance Evaluation of Computer and Communication Systems* -

Markov Chains and Single-Station Queueing Systems Telecommunication Networks Group Technical University of Berlin, Berlin DE, 2007

Time table: Course of 20 hours. Lectures (two hours) on Tuesday and Thursday 2:30 – 4:30 P.M. First lecture on Tuesday, March 17, 2009. Room DEI/G (3-rd floor, Dept. of Information Engineering, via Gradenigo Building).

Course requirements: Basics on Probability theory, Stochastic processes;

Examination and grading: Homework and Oral exam

18 Topics in Quantum Information

Instructor: Francesco Ticozzi. e-mail: `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". Quick overview of the network model.

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

6. **Introduction to Quantum Error-Correction;** Classical and quantum error correction. Stabilizer codes. Concatenation and threshold theorem. Notes on subsystem codes.

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. Lectures (2 hours) on Monday and Wednesday 10:30 – 12:30. First lecture on Monday, January 19, 2009. 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.

19 Wireless Sensor Networks

Instructor: Andreas Willig
e-mail: `awillig@tkn.tu-berlin.de`

Aim: This course provides a first introduction to the field of wireless sensor networks, focusing mostly on protocol aspects.

Topics:

1. **Node and network architectures**
   Node components and their energy consumption
   Energy management strategies
2. **Physical layer aspects**
   Wireless channels: frequency allocation, wave propagation, error characteristics;
   Some example transceivers.
3. **Link-layer aspects**
   Error-control schemes
   Framing aspects
   Addressing considerations
4. **Medium access control**
   Fundamental classes of wireless MAC protocols (TDMA vs. CSMA vs. ...)
   Hidden and exposed terminal problems, solution considerations
   Low duty cycle schemes
   Schedule-based schemes
   Contention-based schemes
5. **Routing and topology control**
   Flat topology control (power control)
   Clustering
   Backbone construction
   Routing protocols
6. **Transport / Reliable delivery in WSNs**
   Single-Packet Delivery
   Block-Delivery
   Stream-Delivery
7. **Data-centric networking**
   Naming and addressing aspects
   Directed diffusion
   Aggregation
8. **IEEE 802.15.4 and ZigBee**

References:

[1] Holger Karl and Andreas Willig, *Protocols and Architectures for Wireless Sensor Network*, John Wiley & Sons, Chichester UK, 2005

Time table: Course of 20 hours. Lectures (two hours) on Tuesday and Thursday 2:30 – 4:30 P.M. First lecture on Tuesday, April 28, 2009. Room DEI/G (3-rd floor, Dept. of Information Engineering, via Gradenigo Building).

Course requirements: Basics on telecommunication systems;

Examination and grading: Oral exam

January 2009

Ph.D. Courses: Room DEI/G

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

February 2009

Ph.D. Courses: Room DEI/G

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
26 10:30 Ticozzi	27 10:30 Byrnes 16:30 Bartolucci	28 10:30 Ticozzi 14:30 Gilardi	29 10:30 Trevisan 14:30 Byrnes 16:30 Bartolucci	30 11:00 Minelli	31	1
2 10:30 Ticozzi 14:30 Altafini	3 10:30 Byrnes 16:30 Bartolucci	4 10:30 Ticozzi 14:30 Altafini 16:30 Gilardi	5 10:30 Trevisan 14:30 Byrnes 16:30 Bartolucci	6 11:00 Minelli	7	8
9 10:30 Ticozzi 14:30 Altafini 16:30 Gilardi	10 10:30 Gilardi 16:30 Bartolucci	11 10:30 Ticozzi 14:30 Altafini	12 10:30 Trevisan 16:30 Bartolucci	13 11:00 Minelli	14	15
16 14:30 Altafini	17	18 14:30 Altafini	19	20	21	22
23 14:30 Altafini	24	25 14:30 Altafini	26	27	28	1

March 2009

Ph.D. Courses: Room DEI/G

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
23 14:30 Altafini	24	25 14:30 Altafini	26	27	28	1
2	3	4 14:30 Villoresi	5	6 10:30 Villoresi	7	8
9 14:30 Codenotti	10 10:30 Codenotti	11 14:30 Villoresi	12	13 10:30 Villoresi	14	15
16 14:30 Codenotti	17 10:30 Codenotti 14:30 Willig-1 16:30 ROOM Oe: Damm - Wimmer	18 14:30 Villoresi	19 14:30 Willig-1 16:30 ROOM Oe: Damm - Wimmer	20 10:30 Villoresi	21	22
23 14:30 Codenotti	24 10:30 Codenotti 14:30 Willig-1 16:30 ROOM Oe: Damm - Wimmer	25 14:30 Villoresi	26 14:30 Willig-1 16:30 ROOM Oe: Damm - Wimmer	27 10:30 Villoresi	28	29
30 14:30 Codenotti	31 10:30 Codenotti 14:30 Willig-1 16:30 ROOM Oe: Damm - Wimmer	1 14:30 Villoresi	2 14:30 Willig-1 16:30 ROOM Oe: Damm - Wimmer	3 10:30 Villoresi	4	5

April 2009

Ph.D. Courses: Room DEI/G

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
30 14:30 Codenotti	31 10:30 Codenotti 14:30 Willig–1 16:30 ROOM Oe: Damm – Wimmer	1 14:30 Villoresi	2 14:30 Willig–1 16:30 ROOM Oe: Damm – Wimmer	3 10:30 Villoresi	4	5
6 14:30 Codenotti	7 10:30 Codenotti 14:30 Willig–1 16:30 ROOM Oe: Damm – Wimmer	8	9 14:30 Willig–1 16:30 ROOM Oe: Damm – Wimmer	10	11	12
13	14 14:30 Willig–1	15	16 14:30 Willig–1	17	18	19
20 16:30 Chiuso	21 16:30 Fagnani	22 14:30 Cibrario 16:30 Chiuso	23 10:30 Cibrario 16:30 Fagnani	24	25 Holiday	26
27 16:30 Chiuso	28 14:30 Willig–2 16:30 Fagnani	29 14:30 Cibrario 16:30 Chiuso	30 10:30 Cibrario 14:30 Willig–2 16:30 Fagnani	1 Holiday	2	3

May 2009

Ph.D. Courses: Room DEI/G

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

June 2009

Ph.D. Courses: Room DEI/G

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

July 2009

Ph.D. Courses: Room DEI/G

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
29	30	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	2

August 2009

Ph.D. Courses: Room DEI/G

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
27	28	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	2	3	4	5	6

September 2009

■ 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 10:30 Pillonetto	15	16	17 10:30 Pillonetto	18	19	20
21 10:30 Pillonetto	22	23	24 10:30 Pillonetto	25	26	27
28 10:30 Pillonetto	29	30	1 10:30 Pillonetto	2	3	4

October 2009

Ph.D. Courses: Room DEI/G

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

November 2009

Ph.D. Courses: Room DEI/G

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
26 10:30 Pillonetto	27	28	29 10:30 Pillonetto 14:30 Verzellesi	30 10:30 Verzellesi	31	1 Holiday
2 08:30 Manduchi	3	4 08:30 Manduchi	5 14:30 Verzellesi	6 10:30 Verzellesi	7	8
9 08:30 Manduchi 14:30 Finesso	10	11 08:30 Manduchi 14:30 Finesso	12 14:30 Verzellesi	13 10:30 Verzellesi	14	15
16 08:30 Manduchi 14:30 Finesso	17	18 08:30 Manduchi 14:30 Finesso	19 14:30 Verzellesi	20 10:30 Verzellesi	21	22
23 08:30 Manduchi 14:30 Finesso	24	25 08:30 Manduchi 14:30 Finesso	26 14:30 Verzellesi	27 10:30 Verzellesi	28	29
30 08:30 Manduchi 14:30 Finesso	1	2 08:30 Manduchi 14:30 Finesso	3	4	5	6

December 2009

Ph.D. Courses: Room DEI/G

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
30 08:30 Manduchi 14:30 Finesso	1	2 08:30 Manduchi 14:30 Finesso	3	4	5	6
7 14:30 Finesso	8 Holiday	9 14:30 Finesso	10	11	12	13
14 14:30 Finesso	15	16 14:30 Finesso	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31	1	2	3