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

Course Catalogue

2011

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.

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1 Adaptive Control

Instructor: Andrea Serrani, The Ohio State University, Columbus, OH – USA
e-mail: serrani@ece.osu.edu

Aim: To give a broad (although necessarily incomplete) treatment of classic and more recent methodologies for adaptive control of linear and nonlinear systems. The emphasis of the course is not on giving a painfully detailed description of several techniques, rather on introducing fundamental concepts and issues in the analysis and design of adaptive control systems.

Topics:

1. **Overview of Adaptive Control Systems.** Direct and indirect adaptive control. The principle of certainty-equivalence.

2. **Advanced tools for stability of non-autonomous nonlinear systems**. Definitions. Converse Lyapunov theorems. LaSalle/Yoshizawa theorem. Passivity theory. Zero-state detectability. Input-to-state stability. Ultimate boundedness. Positive real and strictly positive real transfer functions. Kalman-Yakubovich-Popov lemmas.

3. **Stability of adaptive control systems.** The role of the persistency of excitation condition. Uniform observability. Exponential convergence vs. exponential stability and uniform asymptotic stability.

4. **Model reference adaptive control.** Parameterization of certainty-equivalence controllers. MRAC schemes for linear systems with relative degree one. Uniform global asymptotic stability of MRACs. Extension to higher relative degrees.

5. **Adaptive observers for linear systems.** Systems in adaptive observer form. Filtered transformations.

6. **Direct adaptive control of nonlinear systems.** Adaptive backstepping. Design with overparameterization. Tuning functions method.

7. **Indirect adaptive control of nonlinear systems**. Modular design. Swapping lemmas.

8. **Robust redesign of adaptive controller**. Robustness of adaptive systems. Leakage, dead-zone and projection-based techniques.

9. **Selected topics (if time permits).** The adaptive regulator problem. Adaptive internal model design.

References: There is no official textbook for this course. Notes will be provided that cover most of the above topics. Additional references include:

1. P. Ioannou and J. Sun. *Robust Adaptive Control.* Prentice Hall, Upper Saddle River, NJ, 1996. Available on line at http://www-bcf.usc.edu/ioannou/Robust_Adaptive_Control.htm

2. H. K. Khalil. *Nonlinear Systems,* 3^{rd} *edition.* Prentice Hall, Upper Saddle River, NJ, 2001.

3. E. Panteley, A.Loria. and A.R. Teel. Relaxed persistency of excitation for uniform asymptotic stability. IEEE Transactions on Automatic Control, 46(12):1874-1886, 2001.

4. M. Krstic. Invariant manifolds and asymptotic properties of adaptive nonlinear stabilizers. IEEE Transactions on Automatic Control, 41(6):817 - 829, 1996.

5. I. Kanellakopoulos, P.V. Kokotovic, and A.S. Morse. Systematic design of adaptive controllerr for feedback linearizable systems. IEEE Transactions on Automatic Control, 36(11):1241-1253, 1991.

6. M. Krstic, I. Kanellakopoutos, and P. V. Kokotovic. Adaptive nonlinear control without over-parameterization. Systems & Control Letters, 19(3):177-185, 1992.

7. M. Krstic and P. V. Kokotovic. Control Lyapunov functions for adaptive nonlinear stabilization. Systems & Control Letters, 26(1):17-23, 1995.

8. M. Krstic and P.V. Kokotovic. Adaptive nonlinear design with controller-identifier separation and swapping. IEEE Transactions on Automatic Control, 40(3):426-440, 1995.

9. H.K. Khalil. Adaptive output feedback control of nonlinear systems represented by input-output models. IEEE Transactions on Automatic Control, 41(2):177-188, 1996.

10. A. Isidori, L. Marconi, and A. Serrani, *Robust Autonomous Guidance. An Internal Model Approach*. Springer-Verlag, 2003. Chapter 1, available on line at `http://www.springer.com/engineering/book/978-1-85233-695-0`

Time table: Course of 20 hours (two lectures of two hours each per week). Class meets every Thursday and Friday from 10:30 to 12:30, starting on Thursday, April 7, 2011. Room DEI/G (3-rd floor, Dept. of Information Engineering, via Gradenigo Building).

Course requirements: A beginning graduate-level course in linear systems theory is required. Exposure to nonlinear control theory is desirable (feedback linearization, normal forms). Familiarity with the basic concepts of Lyapunov stability theory is essential.

Examination and grading: Grading will be based on homework and a take-home final exam.

2 Algebraic Tools for the Identifiability of Dynamical Systems

Instructor: M. P. Saccomani, Dept. of Information Engineering, University of Padova,
e-mail: pia@dei.unipd.it

Aim: The course is intended to illustrate the modern methods used to assess a priori identifiability of linear and especially nonlinear dynamical systems. In particular, the course is intended to provide a deep comprehension of the modern commutative algebra and differential algebra tools which can be applied to the study of a priori identifiability of dynamic systems described by polynomial or rational equations [1, 2, 3, 4]. Some hint will be given also to application of these mathematical tools to system and control theory problems. Emphasis will be given to systems describing biological phenomena [5].

Topics: State space models of polynomial and rational dynamical systems. Global and local parameter identifiability. Basic concepts of commutative algebra. Gröbner bases and the Buchberger algorithm. Basic concepts of differential algebra. The Ritt algorithm. Software tool implementations. Case studies.

References

[1] B. Buchberger. Gröbner Bases and System Theory. In Multidimensional Systems and Signal Processing, Kluwer Academic Publishers, Boston (2001).

[2] K. Forsman. *Constructive Commutative Algebra in Nonlinear Control Theory*, Linköping Studies in Science and Technology. Dissertation No. 261, Linköping University, Sweden (1991).

[3] L. Ljung, and S.T. Glad. On global identifiability for arbitrary model parameterizations, Automatica, 30, 2, 265–276 (1994).

[4] M.P. Saccomani, S. Audoly, and L. D'Angiò. Parameter identifiability of nonlinear systems: the role of initial conditions, Automatica, 39, 619–632 (2004).

[5] M.P. Saccomani, S. Audoly, G. Bellu, and L. D'Angiò. Testing global identifiability of biological and biomedical models with the DAISY software, Computers in Biology and Medicine, 40, 402–407 (2010).

Time table: Course of 16 hours. Classes (2 hours) on Monday and Wednesday 10:30-12:30. First lecture on Monday 7 November, 2011. (I take care of the room).

Examination and grading: Homework and a final written examination.

3 Algorithms for Bioinformatics and Computational Biology

Instructors: Alberto Apostolico, Concettina Guerra.
e-mail: axa@dei.unipd.it; guerra@dei.unipd.it

Aim:
The purpose of this Course is to familiarize the students with relevant and current algorithmic problems of bioinformatics and computational biology, and enable them to develop tools for biological data processing, and management.

Topics:
Overview of DNA, RNA and Protein Sequences
Genomics WEB Sites and Data Banks of Proteins, RNA and DNA Sequences, and 3D Structures
Modeling, Combinatorial and Algorithmic Issues
Searching and Matching on Strings and Arrays
Discovery of Repeats, Palindromes and other Regularities in sequences and higher aggregates
RNA and Protein Structure Analysis, Prediction of protein-protein interfaces and protein binding sites
Metabolic Networks, Protein-Protein Interaction networks. Global and local properties of biological networks
Alignment of networks

References:
Bibliographic Sources: selected book chapters, e.g., from the volumes listed below, and archival research papers.
Gusfield, D., Algorithms on Strings, Trees and Sequences - Computer Science and Computational Biology. Cambridge University Press, Cambridge, (1997).
Pevzner, P.A., Computational Molecular Biology: an Algorithmic Approach. MIT Press, Boston (2000)
Baldi, P. and Brunak, S., Bioinformatics: the Machine Learning Approach. MIT Press, Boston (2001)
Apostolico, A. and Z. Galil, Pattern Matching Algorithms. Oxford Univ. Press, New York, (1997)
Apostolico, A., Guerra, C., Istrail, S., Pevzner, P., and Waterman, M., RECOMB06, Proceedings of the Tenth Conference on Research in Computational Molecular Biology, Springer LNCS Vol. 3909, Berlin (2006)

Time table: Course of 20 hours (two lectures of two hours each per week). Class meets every Monday and Wednesday from 14:30 to 16:30. First lecture on Monday, March 28, 2011. Room DEI/G (3-rd floor, Dept. of Information Engineering, via Gradenigo Building).

Course requirements:
No biology background is assumed. An overall graduate level of maturity and a little programming experience will be expected.

Examination and grading: The course grade will be based on reading material, and individually tailored projects.

4 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 Tuesday and Thursday, 10:30 – 12:30. First lecture on Tuesday October 11th, 2011. Room 318 DEI/G (3-rd floor, Dept. of Information Engineering, via Gradenigo Building).

Examination and grading: Homework assignments and final test.

5 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 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*
- *Sylvester and Lyapunov matrix equations*
- *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, 10:30 – 12:30. First lecture on Tuesday, September 13, 2011. **Classroom Oe** (Dept. of Information Engineering, via Gradenigo Building).

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

6 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 10:30 – 12:30. First lecture on Friday, January 14, 2010. 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.

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. 13, 2011. 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 aim of the course aims is to provide an introduction to the study of dynamical models of biological systems, with emphasis on the analysis of nonlinear dynamics. Several of the approaches used in the study of complex biological networks will be presented.

Topics:

1. Qualitative analysis of ODE models
   - linear and nonlinear systems, equilibria and (multi)stability;
   - monotonicity, feedback regulation, sensitivity analysis;
   - phase plane, oscillations;
   - small-scale examples: single and two-species dynamics
2. Dynamical theories for biological networks:
   - 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 online
- U. Alon, "An Introduction to Systems Biology", CRC press, 2007.
- B. O. Palsson, "Systems Biology", Cambridge Univ. Press, 2006.
- H. Othmer, "Analysis of complex networks", Lecture Notes available online

Time table: Course of 16 hours (2 two-hours lectures per week). Class meets every Tuesday and Thursday from 14:30 to 16:30. First lecture on Tuesday, February 1, 2011. 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: Homeworks and final project.

9 Dynamics over networks

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

Aim: In a large variety of scientific and technological fields (social and economic sciences, computer science, engineering, biology), mathematical models based on networks are rapidly increasing their importance. The unifying setting is a large number of 'atoms' possessing a relatively simple time dynamics, who are interconnected together. As a consequence of this interaction, complex global properties emerge in the network: asymptotic convergence to an equilibrium typically dependent on the initial condition, correlation phenomena on several possible network length scales, local and global clustering phenomena. The course wants to give an introduction to some of the hottest and most promising research topics on dynamics over networks. The examples we have in mind and which we want to cover in this course include: epidemics diffusions, opinion spreading models in social and economic networks, cooperative algorithms over sensor networks (consensus), Bayesian learning and games over networks.

Topics:

- A bunch of examples. Social, information, technological, biological networks. Properties of real-world networks: small world effect, clustering, power law degree distribution, scale-free properties. Examples of dynamics on networks: epidemics diffusions, discrete and continuous opinion dynamics models, cooperative algorithms over sensor networks, learning models and strategic games.

- Random graph models. Brief recap of graph concepts: paths, cycles, connectivity, geodetics, diameter, degrees. Branching processes. The Erdos-Renji model: Poisson degree distribution, giant component, phase transitions, diameter. The configuration model: graphs with given degree distributions. Geometric random graphs. The preferential attachment model by Price-Albert-Barabasi.

- A recap of Markov chains: random walks on graphs, invariant probability distributions, convergence, spectral theory, mixing times. Discrete dynamics over networks. Epidemic diffusions: SI and SIR models. Discrete opinion dynamics: voter model, majority models.

- Locally averaging algorithms, convergence to consensus. Gossip models. Continuous opinion dynamics models: The Hegselman-Krause and the Deffuant-Weisbuch models.

- Network learning and games. Bayesian learning on networks. Iterative models. Strategic games on networks. Nash equilibria and convergence issues.

References:

- Jackson, Matthew O., Social and economic networks, Princeton Univ. Press, 2008.

- Vega-Redondo, Fernando, Complex social networks, Cambridge Univ. Press, 2007.

- Durrett, Richard, Random graph dynamics, Cambridge Univ. Press, 2007.

Time table: Course of 20 hours (two lectures of two hours each per week). Class meets every Tuesday and Thursday from 10:30 to 12:30. First lecture on Tuesday, May 10, 2011. Room DEI/G (3-rd floor, Dept. of Information Engineering, via Gradenigo Building).

Course requirements: Basic probability and calculus.

Examination and grading: Homeworks.

10 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 16 hours (two lectures of two hours each per week). Class meets every Wednesday and Friday from 10:30 to 12:30. First lecture on Wednesday, June 8, 2011. 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.

11 Game Theory for Information Engineering

Instructor: Leonardo Badia, e-mail: `leonardo.badia@gmail.com`

Aim: Nowadays, micro-economics instruments have exited their traditional scope and have penetrated into many other research areas. The introduction of such concepts and techniques within scientific reasoning is becoming more and more common, and this especially applies to subjects related to technology and applications, such as information engineering, which are impacted by business models and customer choices. Game-theory has since long represented one of the most interesting branches of micro-economics, particularly due to its wide range of applications and its ability of giving a mathematical formulation to a plethora of problems. Even though the convergence of game-theory and information engineering problems looks very promising, several issues are still open and it is reasonable to think of them as main research directions in the immediate future. For these reasons, it is important for an information engineer to be aware of game-theoretical concepts and instruments, while at the same time, whenever possible, being capable to bring them into use. The knowledge of game-theory fundamentals enables not only the understanding of several contributions recently appeared in the technical literature, but also to identify possible developments of this pioneering work and solutions to the problems they have found.

Topics: The list of topics covered in the course is as follows. First part (game-theory):

- Equilibrium concepts. Pareto dominance.
- Choices and utilities. Rationality. Indifference.
- Games. Non-cooperation. Strategies.
- Nash equilibrium. The Prisoner's dilemma.
- Pure and mixed strategies. Dominance of strategies. Multiple equilibria.
- Dynamic games. Repeated games.
- Cooperation. Pricing. Imperfect/incomplete information. Bayesian equilibrium.
- Signaling. Beliefs.

Second part (application to information engineering):

- Resource sharing, cooperation versus competition.
- Game-theoretic power control and admission control.
- ALOHA as a non cooperative game.
- The price of selfish routing. The Forwarder's dilemma.
- Cooperation enforcement in communication networks.

- Optimization problems in game-theory. How to solve them, and how complex it is.
- Future developments and applications.

References:

[1] R. Gibbons, "Game theory for applied economists."

[2] H. R. Varian, "Microeconomic Analysis."

[3] M. J. Osborne and A. Rubinstein, "A Course in Game Theory."

Further material presented during the course (basically, up-to-date articles recently appeared in the literature).

Time table: Course of 20 hours (2 two-hours lectures per week). Class meets every Wednesday and Friday from 10:30 to 12:30. First lecture on Wednesday, February 23, 2011. Room DEI/G (3-rd floor, Dept. of Information Engineering, via Gradenigo Building).

Course requirements: Very basic principles of calculus (typically, already available after two math undergraduate courses). Basic principles of optimization (a dedicated course on optimization theory might help, although it is not strictly necessary, if some optimization principles are presented in basic math courses). A basic course in Computer Networks and/or Communication Networks is required. The students should master for example concepts like: Ad Hoc Networks, Routing Protocol, ALOHA, Collision Detection. Expertise in the field of Cognitive Networks is useful, but not mandatory.

Examination and grading: The examination is based on a written proposal and an oral presentation. The written part, in the form of an extended abstract limited to about 3 pages including references, should discuss a possible development and application of the topics explored by the course. The student is free to relate it to its own research goals. The oral part concerns a presentation of a recent research paper on course-related subjects. According to the students' availability, this presentation can be given in front of the class. Also for this part the students are invited to relate to their own research activity and are free to present a paper of their choice, if compatible with the course's scope. The presentation is limited to a 20-minute conference-like (aided with slides) setup, plus questions from the teacher and the audience (if present). The grading is determined based on the relevance and technical depth of the proposal, the quality of the oral presentation, and the ability to relate to the course topics.

12 Harnessing Randomness in Information Theory

Instructor: Matthieu Bloch, School of Electrical and Computer Engineering, Georgia Institute of Technology e-mail: `matthieu.bloch@ece.gatech.edu`

Aim: The objective of this course is to study "randomness processing" in information theory, broadly defined as the problem of simulating or transforming stochastic processes. Randomness plays a key role in many information-theoretic problems such as coordination in networks and information-theoretic security. This course will cover several fundamental results related to randomness processing and will build upon these results to tackle more complicated problems such as secret-key agreement from common randomness and secure communication over noisy channels.

Topics:

1. Basic tools of information theory
2. Source resolvability and intrinsic randomness
3. Channel resolvability and channel intrinsic randomness
4. Secrecy from resolvability and intrinsic randomness
5. Common information of random variables
6. Coordination capacity

References:

[1] R. Ahlswede and I. Csiszár. Common Randomness in Information Theory and Cryptography. I. Secret Sharing. *IEEE Transactions on Information Theory*, 39(4):1121–1132, July 1993.

[2] M. Bloch and J. N. Laneman. On the Secrecy Capacity of Arbitrary Wiretap Channels. In *Proceedings of 46th Allerton Conference on Communication, Control, and Computing*, pages 818–825, Monticello, IL, September 2008.

[3] Matthieu Bloch. Channel Intrinsic Randomness. In *Proc. of IEEE International Symposium on Information Theory*, pages 2607–2611, Austin, TX, June 2010.

[4] Imre Csiszár. Almost Independence and Secrecy Capacity. *Problems of Information Transmission*, 32(1):40–47, January-March 1996.

[5] P. Cuff. Communication requirements for generating correlated random variables. In *Proc. IEEE International Symposium on Information Theory ISIT 2008*, pages 1393–1397, 2008.

[6] Te Sun Han. *Information-Spectrum Methods in Information Theory.* Springer, 2002.

[7] T.S. Han and S. Verdú. Approximation Theory of Output Statistics. *IEEE Trans. Inf. Theory*, 39(3):752–772, May 1993.

[8] A. Wyner. The Common Information of Two Dependent Random Variables. *IEEE Trans. Inf. Theory*, 21(2):163–179, March 1975.

[9] A. D. Wyner. The Wire-Tap Channel. *Bell System Technical Journal*, 54(8):1355–1367, October 1975.

Time table: Course of 12 hours (two lectures of two hours each per week). Class meets every Wednesday and Friday from 14:30 to 16:30. First lecture on Wednesday, February 16, 2011. Room DEI/G (3-rd floor, Dept. of Information Engineering, via Gradenigo Building).

Course requirements: Basic notions of information theory (entropy, mutual information, coding theorems) and multi-user information theory. More advanced material will be reviewed in class when relevant.

Examination and grading: Each student must submit a report based on one or several articles related to the material covered in class. Grading will be based on conciseness, precision and relevance of report.

13 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:

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.

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.

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

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

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

A 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 5 and ending on Friday, November 4, 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.

14 Introduction to Quantum Optics I: quantum information and communication

Instructor: Alexander Sergienko
e-mail: `alexserg@bu.edu`

Aim: This part 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 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;
5. quantum interferometry;
6. principles of quantum computation and quantum key distribution.

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 12 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, March 28, 2011. 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.

15 Introduction to Quantum Optics II: quantum measurement, imaging, and metrology

Instructor: Alexander Sergienko
e-mail: `alexserg@bu.edu`

Aim: 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. Generation and detection of entangled states;
2. linear-optical quantum state engineering;
3. high-resolution quantum interferometry;
4. entangled and correlated quantum imaging;
5. dispersion and aberration cancellation in biological imaging;
6. correlated confocal microscopy.

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 12 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, May 9, 2011. 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.

16 Multiple antennas in wireless communications

Instructors: Dr. Luca Sanguinetti and Dr. Giacomo Bacci, Dept. of Information Eng., University of Pisa, Italy (e-mail: `luca.sanguinetti@iet.unipi.it, giacomo.bacci@iet.unipi.it`).

Aim:
Wireless local area networks are currently supplementing or replacing wired networks in homes and offices. In addition, a large number of new applications, including wireless sensor networks, automated highways and factories, smart phones and appliances, and remote telemedicine, are emerging from research ideas to concrete systems. On the other hand, the design of an efficient, reliable, and robust wireless communication network for each of these emerging applications poses many technical challenges. For these reasons, multiple-antenna radio systems have gained a lot of interest thanks to their potential benefits in terms of capacity and/or diversity gain. The aim of this series of lectures is to provide an overview of the fundamental information-theoretic results and practical implementation issues of multiple-antenna networks operating under various conditions of channel state information.

Topics:

1. Introduction and motivation.
2. Capacity of multiple antenna systems:
   (a) Deterministic channel
   (b) Fading channel
3. Space-time coding: principles and applications.
4. Fundamentals of system design with multiple transmit and receive antennas:
   (a) Channel known at the receiver
   (b) Channel known at the transmitter
5. From single-user to multi-user MIMO communications.

References: Reading material will be provided during the course. In addition, a list of excellent books on the subject are reported below.

[1] A. Paulraj, R. Nabar and D. Gore, *Introduction to Space-Time Wireless Communications*, Cambridge University Press, May 2003.

[2] A. Goldsmith, *Wireless Communications*, Cambridge University Press, Aug. 2005.

[3] D. Tse and P. Viswanath, *Fundamentals of Wireless Communication*, Cambridge University Press, May 2005.

[4] E. Biglieri, R. Calderbank, A. Constantinides, A. Goldsmith, A. Paulraj, H. V. Poor, *MIMO Wireless Communications*, Cambridge University Press, Jan. 2007.

Time table: Course of 20 hours (2 two-hour lectures per week). Classes on Mondays 14:30 – 16:30, and Tuesdays 10:30 – 12:30. First lecture on Monday, January 17, 2010. Last lecture will be on Tuesday, February 15, 2010. Room DEI/G (3-rd floor, Dept. of Information Engineering, via Gradenigo Building).

Course requirements: Basic knowledge of wireless communications.

Examination and grading: Homeworks and final oral exam.

17 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/Members/gverzellesi

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.

Time table: Course of 20 hrs (4 hours per week). Lectures (2 hours) on Thursday 4:30 – 6:30 and Friday 2:30 – 4:30. First lecture on Thursday, October 27, 2011. 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.

18 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 Tuesday and Thursday from 10:30 to 12:30. First lecture on Tuesday, June 14, 2011. 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.

19 Stochastic (Ordinary and Partial) Differential Equations

Instructor: Paolo Guiotto (Dept. Pure and Applied Mathematics, Università di Padova), e-mail: `parsifal@math.unipd.it`

Aim: Introduce to the theory of stochastic equations in finite and infinite dimensions.

Topics: The course is divided in two parts. In the Basic Part the aim is to give a quick rigorous introduction to the basic tools of stochastic analysis: brownian motion, stochastic integrals and stochastic differential equations in finite dimensions (which is the starting point for several models in applications). In the Advanced Part the aim is to introduce to the more sophisticated framework of stochastic equations in infinite dimensions. This setting present several applications to stochastic PDE's (a good model for turbulence) and spin systems.
Basic Part. **1.** Brownian Motion — definition, the Levy–Ciesielskii construction, properties of the paths of the BM. **2.** Stochastic Integral — the Wiener integral, predictable processes, martingales, Doob inequalities, construction and properties of the Ito integral. **3.** Stochastic Calculus — Ito formula and applications. **4.** Stochastic Differential Equations — existence, uniqueness, properties of the paths of a solution, Markov property of the stochastic flow.
Advanced Part. **1.** Introduction to stochastic analysis in Hilbert spaces: nuclear brownian motion, Ito integral and Ito formula. **2.** Elements of semigroup theory. **3.** Stochastic evolution equation in Hilbert space. **4.** Applications.

References: Lecture notes will be available with further references.

Time table: Course of 20 hours (two lectures of two hours each per week). Class meets every Tuesday and Thursday from 10:30 to 12:30. First lecture on Tuesday, March 1, 2011. Room DEI/G (3-rd floor, Dept. of Information Engineering, via Gradenigo Building).

Course requirements: Solid knowledge of basic Kolmogorov probability (measure theory based) and basic functional analysis (Hilbert spaces, bounded linear operators, L^p spaces).

Examination and grading: Homeworks on the Basic Part, seminar on a subject assigned by the Instructor on the Advanced Part.

20 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 today for the 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. For this reason, new identification techniques have recently been developed called “subspace methods” which have been demonstrated to be a robust and reliable alternative to classical parameter optimization algorithms. The theoretical foundation of these methods lay in stochastic realization theory and 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. However there are also some drawbacks. First a plethora of algorithms with different acronyms (such as N4SID , PI MOESP, PO MOESP, CCA etc.) is available on the market which makes a motivated choice very difficult for the unexperienced user. It is not clear what differences there are among those algorithms and what are the natural application areas. Second a comprehensive statistical analysis of subspace methods is still to be developed. In fact the statistical analysis of subspace methods is still an active area of research world-wide. This course aims also to provide a pointer to these research areas.

Topics:

1. LINEAR STOCHASTIC MODELS FOR RANDOM PROCESSES: 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 filter

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 (two lectures of two hours each per week). Class meets every Tuesday and Thursday from 14:30 to 16:30. First lecture on Tuesday, March 1, 2011. 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.

January 2011

▬ 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 10:30 Trevisan	14 10:30 Minelli	15	16
17 14:30 Sanguinetti Bac-ci	18 10:30 Sanguinetti Bac-ci	19	20 10:30 Trevisan	21 10:30 Minelli	22	23
24 14:30 Sanguinetti Bac-ci	25 10:30 Sanguinetti Bac-ci	26	27 10:30 Trevisan	28 10:30 Minelli	29	30
31 14:30 Sanguinetti Bac-ci	1 10:30 Sanguinetti Bac-ci 14:30 Altafini	2	3 10:30 Trevisan 14:30 Altafini	4 10:30 Minelli	5	6

February 2011

Ph.D. Courses: Room DEI/G

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
31 14:30 Sanguinetti Bacci	1 10:30 Sanguinetti Bacci 14:30 Altafini	2	3 10:30 Trevisan 14:30 Altafini	4 10:30 Minelli	5	6
7 14:30 Sanguinetti Bacci	8 10:30 Sanguinetti Bacci 14:30 Altafini	9	10 10:30 Trevisan 14:30 Altafini	11 10:30 Minelli	12	13
14 14:30 Sanguinetti Bacci	15 10:30 Sanguinetti Bacci 14:30 Altafini	16 14:30 Bloch	17 10:30 Trevisan 14:30 Altafini	18 10:30 Minelli 14:30 Bloch	19	20
21	22 14:30 Altafini	23 10:30 Badia 14:30 Bloch	24 14:30 Altafini	25 10:30 Badia 14:30 Bloch	26	27
28	1 10:30 Guiotto 14:30 Picci	2 10:30 Badia 14:30 Bloch	3 10:30 Guiotto 14:30 Picci	4 10:30 Badia 14:30 Bloch	5	6

March 2011

▬ Ph.D. Courses: Room DEI/G

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
28	1 10:30 Guiotto 14:30 Picci	2 10:30 Badia 14:30 Bloch	3 10:30 Guiotto 14:30 Picci	4 10:30 Badia 14:30 Bloch	5	6
7	8 10:30 Guiotto 14:30 Picci	9 10:30 Badia	10 10:30 Guiotto 14:30 Picci	11 10:30 Badia	12	13
14	15 10:30 Guiotto 14:30 Picci	16 10:30 Badia	17 10:30 Guiotto 14:30 Picci	18 10:30 Badia	19	20
21	22 10:30 Guiotto 14:30 Picci	23 10:30 Badia	24 10:30 Guiotto 14:30 Picci	25 10:30 Badia	26	27
28 10:30 Sergienko-I 14:30 Apostolico-Guerra	29 10:30 Guiotto 14:30 Picci	30 10:30 Sergienko-I 14:30 Apostolico-Guerra	31 10:30 Guiotto 14:30 Picci	1	2	3

April 2011

▬ Ph.D. Courses: Room DEI/G

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

May 2011

▬ Ph.D. Courses: Room DEI/G

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

June 2011

Ph.D. Courses: Room DEI/G

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

July 2011

Ph.D. Courses: Room DEI/G

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

August 2011

Ph.D. Courses: Room DEI/G

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
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

September 2011

▬ 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 10:30 Damm-Wimmer Room Oe	14	15 10:30 Damm-Wimmer Room Oe	16	17	18
19	20 10:30 Damm-Wimmer Room Oe	21	22 10:30 Damm-Wimmer Room Oe	23	24	25
26	27 10:30 Damm-Wimmer Room Oe	28	29 10:30 Damm-Wimmer Room Oe	30	1	2

October 2011

▬ Ph.D. Courses: Room DEI/G

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

November 2011

▬ Ph.D. Courses: Room DEI/G

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

December 2011

Ph.D. Courses: Room DEI/G

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
28 10:30 Saccomani	29	30 10:30 Saccomani	1	2	3	4
5	6	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