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

Course Catalogue

2012

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.

Due to unavailability of the graduate and undergraduate courses schedule possible conflicts may arise for some instructors. The schedule presented here is then subject to changes, which will be notified by the secretariat as soon as possible.

Contents

1 The Behavioral Approach to Control of Distributed Systems

Instructor: Shiva Shankar, Chennai Mathematical Institute, Chennai, India.
e-mail: `sshankar@cmi.ac.in`

Aim: To introduce the key ideas of the behavioral approach to control of open dynamical systems, and to show how the ideas of J.C.Willems, developed first as a generalization of the Kalman theory to the case of lumped systems, carry over naturally to distributed systems. Just as linear algebra is the language in which the Kalman theory of state space sytems is written, the behavioral theory of distributed systems is written in the language of commutative algebra. The course will *not* assume any background, but will develop the required results from commutative and homological algebra along the way.

Topics:

Lecture 1. A quick review of controllability in the Kalman theory of state space systems; how do we generalize this theory to the case when first order operators are replaced by operators of arbitrary order and when we ignore input-output structures.

Lecture 2. A little commutative algebra (commutative rings, modules, localization, Hom and tensor product).

Lecture 3. The generalization to distributed systems (described by constant coefficient partial differential operators); controllability as a patching problem, controllability versus potential.

Lecture 4. Necessary and sufficient conditions for controllability of $\mathcal{C}^\infty$ behaviors; controllable and autonomous behaviors.

Lecture 5. A little more commutative and homological algebra (injective and flat modules); The Fundamental Principle of Malgrange-Palamodov (statement).

Lecture 6. Consequences of the Fundamental Principle for $\mathcal{C}^\infty$ behaviors - elimination, lattice structure etc.

Lecture 7. Behaviors in other function spaces such as the space of compactly supported smooth functions; the Nullstellensatz problem for systems of partial differential equations, the problem of calculating Willems closures.

Lecture 8. A last bit of commutative algebra (associated primes, primary decomposition); the Nullstellensatz for systems of PDE.

Lecture 9. Other structures on behaviors - causality, interconnections, feedback, stability.

Lecture 10. Further research directions.

References: There is no textbook in the subject (yet) but I shall provide notes. Apart from papers in the subject, there is a comprehensive survey - J.C.Willems: *The behavioral approach to open and interconnected systems*, IEEE Control Syst. Mag., 27:46-99, 2007.

Time table: Two 2-hour lectures per week, per 5 weeks, starting from September 18.

Course requirements: The basics of Kalman's state space theory, linear algebra.

Examination and grading: Homework and final examination.

2 Algebraic tools for the identifiability of dynamical systems

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. Grbner 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 Wednesday 7 November, 2012. Room DEI/G **Examination and grading**: Homework and a final written examination.

3 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 September 10th, 2012. Room DEI/G (3-rd floor, Dept. of Information Engineering, via Gradenigo Building).

Examination and grading: Homework assignments and final test.

4 Applied Linear Algebra

Instructor:

Harald Wimmer, University of Würzburg, Germany

e-mail: `wimmer@mathematik.uni-wuerzburg.de`

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

Topics:

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

References:

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

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

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

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

Time table: Course of 16 hours (2 two-hours lectures per week): Classes on Tuesday and Thursday, 10:30 – 12:30, March 13, March 15, March 20, March 22, March 27, March 29, April 17, April 19.

Classroom Oe (Dept. of Information Engineering, via Gradenigo Building).

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

5 Digital Processing of Measurement Information

Instructor: Prof. Claudio Narduzzi, Dept. Information Engineering (DEI), Universit di Padova, e-mail: narduzzi@dei.unipd.it

Aim: Whenever reasearch involves experimental activities, there is a need to characterise measuring equipment, assess the accuracy of data and, most often, process raw data to extract relevant information. The course introduces advanced measurement algorithms, together with the conceptual tools that allow their characterisation in a probabilistic framework. This will provide the student with the skills required to analyse a measurement problem, process experimental data and correctly approach the analysis of uncertainty.

Topics:

1. Uncertainty, quantisation and the additive noise stochastic model: a reappraisal.
2. Characterisation of waveform digitisers and data acquisition systems.
3. Analysis of signal processing algorithms: statistical properties of discrete Fourier transform-based spectral estimators, least squares regression and the Cramr-Rao bound.
4. Compensation of measurement system dynamics: inverse problems and ill-posedness.
5. Multi-resolution analysis and the characterisation of clock stability
6. Model-based measurements and compressed sensing.
7. The evaluation of uncertainty in measurement: ISO Guide probability-based approach and the alternative approach based on the theory of evidence.

References: Lecture notes and selected reference material will be handed out during the course.

Time table: Course of 16 hours (two two-hour lectures per week): Classes on Monday and Thursday, 10:30 to 12:30 A.M., first lecture on April 23rd, 2012. Room: DEI/G

Course requirements: – **Examination and grading**: Final project assignment.

6 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. 12, 2012. Room DEI/G (3-rd floor, Dept. of Information Engineering, via Gradenigo Building).

Course requirements: None.

Examination and grading: Oral exam.

7 Topics in Quantum Information

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

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

Topics:

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

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

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

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

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

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

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

Time table: 16 hours. Lectures starting from 13 February, monday and wednesday at 10:30 am.

Course requirements: Standard linear algebra and probability theory.

Examination and grading: Homeworks and final project.

8 Polyhedral Methods for Integer Linear Programming

Instructor: Matteo Fischetti, Dept. of Information Engineering, University of Padova.
e-mail: `matteo.fischetti@unipd.it`

Aim: The purpose of this Course is to introduce polyhedral methods for Integer Linear Programs and to enable the students to develop sound polyhedral (branch-and-cut) solution methods.

Topics:

- Basic Linear and Integer Programming
- The branch-and-cut paradigm
- Linear Programming geometry: polyhedra, dimension, vertices, faces, and facets
- Proving the facet-defining property: direct and indirect methods
- Polyhedral structure of the Asymmetric Travelling Salesman Problem
- Design of a branch-and-cut algorithm for the Asymmetric Travelling Salesman Problem

References: 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 Friday from 12:00 to 14:00. First lecture on Friday, March 23, 2012. Room DEI/201 Dept. of Information Engineering, DEI/A Building).

Course requirements: Basic courses on linear algebra and graphs.

Examination and grading: Grading is based on a project assigned by the Instructor.

9 Fluid mechanics for the functional assessment of cardiovascular devices

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

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

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

References:

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

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

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

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

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

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

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

Time table: Course of 12 hours. Lectures (2 hours) on Teusday 10:30 12:30. starting on Tuesday, Oct. 16, 2012 and ending on Tuesday, Nov. 20, 2012. Room 201 DEI/A.

Course requirements: Fundamentals of Fluid Dynamics.

Examination and grading: Homework assignments and final test.

10 Game Theory for Information Engineering

Instructor: Leonardo Badia, DEI, University of Padova 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).

Classes on Thursday and Friday. Lectures on: February 9, 2012 (10:30–12:30), February 10, 2012 (10:30–12:30), February 16, 2012(10:30–12:30), February 17, 2012 (10:30–12:30), February 23, 2012 (10:30–12:30), February 24, 2012 (10:30–12:30), March 1, 2012 (10:30–12:30), March 2, 2012 (10:30–12:30), March 8, 2012 (10:30–12:30), March 9, 2012 (10:30–12:30).

Room 201 DEI/A

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.

11 Tissue engineering: principles and applications

Instructor: Andrea Bagno, Department of Chemical Process Engineering (DPCI), University of Padova, e-mail: `andrea.bagno@unipd.it`

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

Topics:

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

References

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

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

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

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

Time table: Course of 12 hours (2 two-hours lectures per week), Classes on Monday and Wednesday, 10:30 12:30. First lecture on January 16, 2012. Room DEI/G

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

Examination and grading: homework assignments and final test.

12 Electrostatic Discharge in Integrated Circuits

Instructor: Gaudenzio Meneghesso, Dept. Ingegneria dellInformazione (DEI), University of Padova, e-mail: gaudenzio.meneghesso@unipd.it

Aim: This course is intended to provide an introduction coverage of the Electrostatic Discharge (ESD) problem in modern Integrated Circuits (ICs). There are several reason that indicate the ESD problem as one of the most critical issue in modern ICs to be faced, among others: a) with the continuous technology scaling down, in the deca-nanometer dimension, devices can not sustain voltages larger than 1 V, hence these devices are extremely sensitive to electrostatic discharge and an adequate ESD protection become quite difficult to provide; b) very high speed RF circuits needs ESD protection devices that do not affect their RF performances by altering the input/output matching, so suitable ESD protection elements must be developed; c) automotive industry is making very comfortable and secure cars by filling them with as much electronics as possible working in a very hostile ambient, a suitable ESD protection of these devices is not trivial. These are only few examples that however give an impression of how much critical will be the ESD aspect in the future ICs.

Topics:

1. Basics of the Electrostatic Discharge phenomena;

2. Test Methods;

3. Active and passive ESD protection;

4. Device Physics of the most common ESD protection elements;

5. Characterization of ESD protection elements;

6. Failure Modes, Reliability Issues and Case Studies;

7. Circuit Simulation basics: approaches and applications.

References:

[1] Amerasekera, C. Duvvury, ESD in Silicon Integrated Circuits, Wiley 2002 (Second Edition).

[2] Z. H. Wang, On Chip ESD Protection for Integrated Circuits, Kluwer Academic Publisher, 2002.

[3] S. Dabral, T. J. Maloney, Basic ESD and I/O Design, Wiley Interscience, 1998.

Time table: Course of 20 hours (2 two-hours lectures per week): Classes on Monday 14:30 - 16:30 and Thursday, 14:30 - 16:30. First lecture on October 8, 2012. (This is a tentative schedule)

Course requirements: Introductory course of device physics: Microelectronics

Examination and grading: Design and SPICE verification of an ESD protection network.

13 Introduction to Quantum Optics: quantum information and communication

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

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

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

Topics:

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

References:

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

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

Additional reading:

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

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

Time table: Course of 20 hours (two lectures of two hours each per week). As far as the commencement date is concerned please contact the instructors.

Course requirements: Basic concept of Quantum Physics.

Examination and grading: Homework and final exam.

14 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 12, 2012. 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.

15 Mathematical modeling of cell Biology

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

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

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

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

1. C.P. Fall, E.S. Marland, J.M. Wagner, J.J. Tyson. *Computational Cell Biology*. Springer, NY, USA (2002).
2. J. Keener, J. Sneyd: *Mathematical Physiology*. Springer, NY, USA (2004).

Time table: Course of 20 hours (2 two-hours lectures per week). Class meets every Tuesday and Thursday from 10:30 to 12:30. First lecture on Tuesday, October 23, 2012. (I take care of the room).

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

Examination and grading: Homeworks and/or final project.