PDEEC Curricular Units

Curricular Files

Important Note:

These curricular files are indicative. The professors and content of this curricular files may vary from year to year. In a specific academic year, some of the courses may not be offered.

PDEEC Curricular Units

1st Semester

Ajuda Multicritério à Decisão / Multicriteria Decision Aiding

Professor: Manuel António Cerqueira da Costa Matos

Learning outcomes of the curricular unit:

Students should be able to:

- Discuss the decision-aid problematic in problems with multiple criteria and uncertainty.

- Use formal models to represent decision situations

- Choose and apply systematic decision-aid methodologies, including using software tools and interaction with the decision maker.

- Set up evaluation methodologies for public tenders.

Syllabus:

- Multicriteria decision-aid. Concepts and terminology. The role of the Decision Maker. Preference modeling.

- Multiattribute problems. Trade-off techniques, value functions and the French/European School. Setting up evaluation methodologies for public tenders and applying them. Sorting problems.

- Data envelopment analysis (DEA).

- Multiobjective problems. Techniques for generating nondominated alternatives. Interactive methods.

- Uncertainty and Risk. Decision trees. Decision paradigms. Utility theory. Robust approaches. Methodologies based on multiple risk and opportunity indices.

- Analysis of case studies.

Teaching methodologies (including evaluation):

The course will be organized around lectures, complemented by students' autonomous work, which will be organized around group assignments around case studies and small problems.

A strong interaction and participation of students, leading to a real active learning environment, will be sought in the lectures, by resorting to differentiated learning strategies.

Evaluation will be based on the discussion of case studies and a final exam.

Main References

- *Robert T. Clemen, Terence Reilly;Making hard decisions with decision tools. ISBN: 0-534-36597-3*
- *Denis Bouyssou... [et al.];Evaluation and decision models. ISBN: 0-7923-7250-6*
- *Valerie Belton, Theodor J. Stewart;Multiple criteria decision analysis. ISBN: 0-7923-7505-X*

Análise, Classificação e Processamento de Sinal / Signal Analysis, Classification and Processing

Professor: Diamantino Rui da Silva Freitas; Sérgio Reis Cunha (Docente Responsável)

Learning outcomes of the curricular unit:

To review the knowledge and mathematical bases of signal processing in a uniformization perspective.

To learn the third cycle of studies advanced topics in signal processing.

To learn how to combine and apply knowledge into projects.

To learn how to evaluate solutions.

Learning outcomes of the curricular unit:

To know and be able to apply: analysis and synthesis of signals and systems with transforms in the continuous and the discrete-time domains; multiresolution/multirate processing, analysis and synthesis and filter banks; optimization and estimation techniques, parametric analysis and synthesis techniques; stochastic systems analysis, Wiener and Kalman filtering, feature extraction and signal detection; cepstral analysis, synthesis and deconvolution; multi-channel analysis and instrumentation.

Syllabus:

1. Introduction to signal processing. 2. Multirate processing; Interpolation and decimation; Polyphase decomposition. 3. Stochastic processes; Correlation functions, time averages and the power spectrum; Gaussian Processes and white noise assumptions; Linear systems with random inputs; Representation of narrowband systems; The matched and the Wiener filters in continuous time. 4. Optimal digital signal processing and Spectral estimation; Linear prediction and optimum linear filters; Lattice filters; The Levinson Recursion; AR and ARMA filters; System modeling, identification and processing by least squares methods; Parametric modeling (AR, MA and ARMA); Adaptive filtering and the LMS algorithms; Channel equalization. and signal enhancement. 5. Spectral estimation; Periodogram, correlogram, DFT and modern parametric estimation methods; Multi-channel spectral estimation; cross-correlation; croos-spectrum; coherence. 6. Cepstral analysis and homomorphic deconvolution.

Teaching methodologies (including evaluation):

Presentation of topics, examples of applications followed by problems to be solved. Proposal of exercises for autonomous work and their resolution. Proposal of home assignments and small projects.

Distributed evaluation without final exam. students in their creative application, as well as of their writing and oral presentation skills.

Main References

- *Alan V. Oppenheim, Ronald W. Schafer, John R. Buck; Discrete-time signal processing. ISBN: 0-13-083443-2*
- *Dimitris G. Manolakis, Vinay K. Ingle, Stephen M. Kogon.; Statistical and adaptive signal processing. ISBN: 1580533663*

Aprendizagem Computacional / Machine Learning

Professor: Jaime dos Santos Cardoso

Learning outcomes of the curricular unit:

The course is intended for students who are interested in Machine Learning. Machine Learning is a foundational discipline of the Information Sciences. It combines elements from Mathematics, Computer Science, and Statistics with applications in Biology, Physics, Engineering and any other area where automated prediction is necessary.

The aim of the course is to present some of the topics which are at the core of modern Machine Learning, from fundamentals to state-of-the-art methods. Emphasis will be put both on the essential theory and on practical examples and lab projects. Each exercise has been carefully chosen to reinforce concepts explained in the lectures or to develop and generalize them in significant ways.

Syllabus:

1. Introduction to Bayes decision: likelihood function; optimal Bayes decision; predictive problems; Inference versus decision

2. Linear Models for regression: criteria; bias/variance decomposition and Gauss-Markov theorem; Ridge and Lasso regression; Bayesian regression.

3. Linear models for classification: discriminant analysis and Fisher discriminants; logistic regression; perceptron; SVM; large margin methods.

4. Non-linear regression and classification: basis expansions; neural networks; kernels and RKHS; trees; prototype and nearest-neighbour methods; additive models and boosting

5. Unsupervised learning: clustering; mixtures; SOM; other problems

6. Learning theory and model selection; expected and empirical risks; cross-validation; risk minimization; generalization bounds; capacity measures.

7. Graphical Methods: Bayesian networks; conditional independence; Markov random fields; inference.

8. Sequential Data: Markov models.

Teaching methodologies (including evaluation):

The course will be organised in one weekly lecture and practical/lab periods. During the lectures the course topics will be presented. The recitation/lab periods will be used for solving exercises and for the development of the assignments.

Distributed evaluation with final exam

Main References

- *Bishop, Christopher M.; Pattern recognition and machine learning. ISBN: 978-0-387-31073-2*
- *Hastie, Trevor; The elements of statistical learning. ISBN: 0-387-95284-5*
- *Theodoridis, Sergios 1951-; Pattern recognition. ISBN: 0126858756*
- *Duda, Richard O.; Pattern classification. ISBN: 0-471-05669-3*
- *Mitchell, Tom M.; Machine learning. ISBN: 0-07-115467-1*

Conversão de Potência / Power Conversion

Professor: Adriano da Silva Carvalho

Learning outcomes of the curricular unit:

To analyse the operation of modern high performance power electronics converters in terms of different topologies, control methods. The objective is the student to get knowledge in applying the power converter as adapter of the power waveform independently from application domain gaining ability:

- To adopt a topology for a well-established power/energy conversion;
- To analyse power flow and input and output waveforms;
- To control power converter operation.

Syllabus:

Pulse converters. Modeling with instantaneous and average models. Linearization. Design of converters. Control requirements for active and reactive power flow. Methods for grid synchronization. Scalar vector control and sliding mode control. Direct power control. Fuzzy, neural network and computational intelligence control methods.

Multilevel converters. Analysis of NPC, nested-cell topologies, and cascaded H-bridges. Control methods. Closed-loop control. Application of multilevel converters.

Active power filters: voltage and current source structures. Topologies. Four wire active power filters. Control strategies: voltage control, reactive power compensation and harmonics cancellation. Control methods: scalar and vector control methods, pq theory.

Analysis and synthesis of EMI generated by power electronics converters.

Thermal modelling of semiconductors and converters.

High performance and dynamics analysis by simulation of power electronics converters based systems.

Teaching methodologies (including evaluation):

Classes will include lectures, involving the use of simulation software and oral presentations from students reporting conclusions from their oriented study and research in specific domains.

Distributed evaluation with final exam. The components for student evaluation are:

- Assignments
- Projects
- Exam

Each component will receive a grading in percentage.

Main References

- *M. Kazmierkowski, R. Krishnan, F. Blaabjerg; Control Problems in Power Electronics, Academic Press, 2002*
- *B. Wu; High Power Converters and AC Drives, Wiley-IEEE Press, 2006*
- *H. Akagi, E. Watanabe, M. Aredes; Instantaneous Power Theory and Applications to Power Conditioning, Wiley-IEEE Press, 2007*

Heurísticas e Metaheurísticas / Heuristics e Metaheuristics

Professor: Bernardo Sobrinho Simões de Almada Lobo

Learning outcomes of the curricular unit:

It is expected to endow the students with skills to:

- identify optimization problems and approach them in a structured way;

- define the most adequate abstraction level to model optimization problems for an algorithmic approach to their resolution.

- identify the algorithmic techniques to solve a particular optimization problem;

- use heuristics and metaheuristics methods to obtain solutions for the problems;

- implement, test and validate, search methodologies to solve different classes of optimization problems.

Syllabus:

Heuristics and Local Search
Constructive heuristics
Exhaustive search
Neighbourhood structures
Local search
Divide and Conquer and Dynamic Programming
Branch and Bound and A Algorithms*
Dealing with infeasibility in search methods
Non-populational metaheuristics
- Simulated Annealing
- Tabu Search
- GRASP
- Variable Neighbourhood Search
- Other non-populational metaheuristics
Populational metaheuristics
- Genetic algorithms and evolutionary programming
- Ant Colonies
- Other populational metaheuristics

Teaching methodologies (including evaluation):

Classes will be mainly organized as lectures, in opposition to home work that will mainly be organized around assignments and therefore will take place in off class periods. A strong interaction and participation of students, leading to a real active learning environment, will be sought in the lectures. In concrete the following learning strategies will be used:

- Group discussion based on scientific papers
- Small problems discussion and resolution
- Exploitation of alternative problem development paths
- Resolution of an optimization project

Main References

- *Michaelwicz, Zbigniew; Fogel, David B; How to Solve It: Modern Heuristics, Springer-Verlag, 2004. ISBN: 3-540-22494-7*
- *El-Ghazali Talbi; Metaheuristics. ISBN: 978-0-470-27858-1*

Inteligência Computacional e Sistemas de Potência / Computational Intelligence and Power Systems

Professor: Vladimiro Henrique Barrosa Pinto de Miranda

Learning outcomes of the curricular unit:

This course aims at making students familiar with a number of tools pertaining to the domain of computational intelligence, which will be useful in dealing with power and energy system models in their research activity, in other courses and in their professional life. The students having taken this course shall be able to develop models under the computational intelligence paradigm, to program algorithms and to discuss their results in terms of accuracy, effort and credibility.

Syllabus:

The course syllabus includes:

- Evolutionary Computing and its variants;

- Particle Swarm Optimization and Evolutionary Particle Swarms;

- Application of evolutionary and swarm algorithms to power system problems and discussion of results. Application in reliability;

- Introduction to Fuzzy Inference Systems (FIS). Takagi-Sugeno FIS;

- Feedforward Neural Networks. Interpretation in the information flow context;

- Concept of mappers. Criticism of Minimum Square Error (MSE) as a training cost function. Introduction to Information Theoretic Learning (ITL). Training mappers under an Entropy-related MEE cost criterium. Application of mappers in power system problems;

- Clustering using ITL concepts. Renyi Entropy and Cauchy-Schwarz divergence. Mean shift algorithms. Application to scenario reduction in wind power;

- Polynomial networks: introduction to GDHM (Group Data Handling Method);

- Construction/training algorithm. Application of GDHM in power system problems.

Teaching methodologies (including evaluation):

Lectures and assignments.

Distributed evaluation with final exam

In order to obtain a passing mark, the student must complete all the assignments with a positive evaluation and have a minimum of 8/20 in the final exam.

To compute the final mark, the exam will entre with a weight of 40% and the set of assignments with a weight of 60%.

Main References

As supplied along with classes. The main reading material consists of scientific papers in several journals. There is no book that may be named as main reference.

Manipuladores Robóticos / Robotic Manipulators

Professor: Paulo José Cerqueira Gomes da Costa

Learning outcomes of the curricular unit:

This graduate course on Robotics Manipulators aims to give the student the ability to understand and apply the recent advances in this field. There is a text book together with a list of selected original research papers in order to allow the students to follow the advances in the addressed topics. The course main topics are: rigid body dynamics, rotation representation, forward and inverse kinematics, the Jacobian, path and trajectory planning, joint control, dynamics, multivariable control, advanced external sensors, rapid teaching and programming interfaces.

Syllabus:

1. Rigid body dynamics
- *Rigid body dynamics*
- *Rotation representation*
- *Quaternions*

2. Forward and inverse kinematics
- *a. The Denavit-Hartenberg convention.*
- *b. Inverse kinematics.*

3. The Jacobian
- *Skew simetric matrices.*
- *Derivation of the Jacobian.*
- *Singularities.*
- *Static force/torque relationships.*
- *Inverse velocity and acceleration.*
- *Manipulability.*

4. Path and trajectory planning
- *Trajectory planning.*
- *Potential fields.*
- *Probabilistic roadmap.*

5. Joint control
- *Actuator dynamics.*
- *Joint model.*
- *Set-point tracking*
- *PD, PID, Feedforward and state space design.*

6. Manipulator dynamics
- *Equations of motion.*
- *Properties of robot dynamic equations.*

7. Advanced external sensors
- *Force/torque sensors.*
- *Vision based sensors.*

8. Rapid teaching and programming interfaces
  - *Programming by demonstration.*
  - *Programming using advanced input-output devices.*
  - *Using CAD files*

Teaching methodologies (including evaluation):

Classes will be used to present the course topics will be presented and also for solving exercises and for the development of the assignments by the students.

Distributed evaluation without final exam.

Main References

- *Spong, Mark W.; Robot modeling and control. ISBN: 0-471-64990-2*

Mercados e regulação / Markets and Regulation

Professor: João Paulo Tomé Saraiva

Learning outcomes of the curricular unit:

As a result of attending this course and having a positive final grading, the students will gain a number of learning outcomes in areas related with the organization and operation of whole sale electricity markets, costs allocation methods, tariff structures and tariff regulatory strategies to be adopted by regulatory agencies. This involves analyzing the most relevant models that have been used to form the new skeleton of power systems; regulation and regulatory approaches; nodal marginal pricing; congestion rent and computation of nodal prices using dual variables of optimization problems, analysis of the Portuguese tariff code as an illustration of the unbundling of the integrated tariff systems in order to create additive non-biased systems. An important objective of this course is to contribute to develop the capacity of the students to work autonomously, to do bibliographic research, to prepare written reports and to deliver oral presentations.

Syllabus:

The contents of this course include:

- *analysis of the models and structures resulting from the adoption of market mechanisms in the electricity sector;*
- *analysis of the EU Directives on the Internal Electricity Market and the structure and operation in the Nordpool, UK, Spain and the Iberian Electricity Market;*
- *access tariffs as a crucial element for the success of electricity market implementations. Tariff approaches with particular emphasis on nodal pricing;*
- *the scheduling of ancillary services in this new structure. Discussion on the unbundling of ancillary services from active power and implementation of particular markets for some ancillary services;*
- *the concept of regulation, its historical evolution and regulatory strategies;*
- *analysis of the Portuguese tariff system as an example of an unbiased additive system.*

Teaching methodologies (including evaluation):

According to the indications in the Plan of Studies of the program, the course on Markets and Regulation involves classes in order to expose the topics of the program and to present and discuss illustrative examples. These classes will use power point files that will be made available to the students as complementary studying material. Along the classes several case studies will be discussed in order to highlight specific topics to be addressed. Finally, the students will present the results obtained in the assignments they are asked to complete along the course and they will deliver a specific presentation regarding a topic they select in the scope of the course. This oral presentation corresponds to a specific assignment and has a weight of 10% in the final grade. Distributed evaluation with final exam.

Main References

- *João Saraiva, José Luís Silva, Maria Teresa Leão; Mercados de Electricidade - Regulação e Tarifação de Uso das Redes, FEUP Edições, 2002. ISBN: 972-752-053-7*
- *S. Stoft; Power System Economics, IEEE/Wiley, 2002. ISBN: 0-471-15040-1*
- *G. Tothwell, T. Gomez (edt); Electricity Economics - Regulation and Deregulation, IEEE Press Series on Power Engineering, 2003. ISBN: 0471234370*

Métodos em Espaços Vetoriais / Vector space methods

Professors: Maria do Rosário Marques Fernandes Teixeira de Pinho; Maria Margarida de Amorim Ferreira

Learning outcomes of the curricular unit:

This is an introductory course in functional analysis and infinite dimensional optimization, with applications in least-squares estimation, nonlinear programming in Banach spaces, optimal and robust control. The repertoire of analytical tools related to linear spaces provides the students with the facility to investigate new theoretical concepts in electrical engineering specialties

Syllabus:

1: Optimization in finite dimensional spaces versus infinite dimensional spaces

2. Normed linear Spaces

3. Hilbert Spaces- Minimum norm problems

4. Dual Spaces: Hahn- Banach Space and its application to minimum norm problems

5. Linear Operators and adjoints

6. Optimization with and without constraints

7. Optimal Control and Maximum Principle

8. Numerical Methods

9. Other relevant topics (is the time permits)

Teaching methodologies (including evaluation):

There will be expository lectures in the end of which a list of problems are proposed. Such lectures are followed by discussion classes to treat problems assigned on the subject.

Distributed evaluation with final exam

Main References

- *Polak, E; Optimization: Algorithms and Consistent Approximations, Springer, New York, 1997. ISBN: 0-387-94971-2*
- *Boyd, S. and Vandenberghe, L; Convex Optimization, Cambridge University Press, 2005. ISBN: 0 521 83378 7 (also available online at http://www.ee.ucla.edu/~vandenbe/cvxbook/bv_cvxbook.pdf)*
- *Varaiya, Pravin; Lecture notes on optimization, e-book, http://paleale.eecs.berkeley.edu/~varaiya/papers_ps.dir/NOO.pdf*
- *Luenberger, David G.; Optimization by Vector Space methods*

Sinais, Dinâmica e Controlo / Signals, Dynamics and Control

Professors: João Abel Peças Lopes; Maria Helena Osório Pestana de Vasconcelos(

Learning outcomes of the curricular unit:

Be able to:

1- Master the modeling of conventional power system components, for dynamic analysis studies.
2- Use dynamic simulation software for the purpose of developing transient and dynamic analysis.
3- Understand several dynamic phenomena that may lead to security loss.
4- Understand the operation of the primary, secondary and tertiary load-frequency control system.
5- Characterize power system oscillations using modal analysis.
6- Be familiar with the procedures for tuning power system stabilizers to increase the damping of electromechanical modes of oscillation.
7- Understand emergency control actions like load shedding triggered by frequency or voltage.
8- Be aware of the methodology required to apply automatic learning techniques in order to obtain on-line dynamic security assessment tools.

Syllabus:

1-Detailed modeling of conventional power system components, for dynamic analysis studies.

2- Description of the dynamic behavior and management of primary, secondary and tertiary load-frequency control systems in large interconnected power systems.

3- Modeling and study the dynamic response of the primary and secondary load-frequency control systems, using simulation software.

4- Analysis of power system electromechanical modes using eigenvalue-based methods. Design and tuning of power system stabilizers (PSS).

5- Description of emergency control actions and study of advanced stability enhancement techniques.

6- Application of automatic learning techniques in order to provide fast dynamic security assessment of power systems. The specific situations of power systems, with high penetration of wind power production, will be analyzed.

Teaching methodologies (including evaluation):

Classes will include lectures and a oral presentations from students reporting conclusions from their oriented study and research in specific domains (in this case open discussions will be fostered). Distributed evaluation with final exam.

Main References

- *P. Kundur, Power System Stability and Control, New York: McGraw-Hill, 1994.*
- *G. Rogers, Power System Oscillations, M. A. Pai, Ed., Norwell: Kluwer Academic Publishers, 2000.*
- *M. A. Pai, D. P. S. Gupta, and K. R. Padiyar, Small Signal Analysis of Power Systems. Harrow: Alpha Science International, **2004.***

Sistemas de Acontecimentos Discretos/ Systems with Discrete Events

Professor: Fernando Manuel Ferreira Lobo Pereira

Learning outcomes of the curricular unit:

A unified modeling and analysis formal framework for discrete event driven dynamic systems and some associated key analytical tools are introduced and discussed. The systemic approach encompasses untimed, timed, deterministic and stochastic systems, providing the basis to handle systems specified by networks of queues. For the class of Markov processes, which are amenable to more traditional analytic methods, control issues will be also addressed.

For more general classes of systems, simulation methods will be considered and sensitivity analysis and sample path constructive techniques are presented. The spectrum of topics is very vast and not all the items might be covered with the same intensity. This enables to focus on issues selected to suit the interests of the students' research plans.

Competences: Acquisition of the scientific basis, handle - modeling, analysis, control synthesis and optimization - discrete event systems. Mastering of the underlying methods and tools.

Syllabus:

1. *Introduction - Discrete-Event Systems.*
2. *Untimed Models - Languages and Automata Theory, Petri Nets, Analysis of Untimed Models.*
3. *Timed Models - Timed State Automata, Timed Petri Nets, Algebra max-plus.*
4. *Stochastic Timed Models - Introduction to Stochastic Processes, Stochastic Timed State Automata, Generalized Semi-Markov Process and Extensions, Poisson Process.*
5. *Markov Chains - Models, Transition Probability Matrix, Transient and Steady State Analysis for Discrete-Time and Continuous-time Markov Chains.*
6. *Controlled Markov Chains - Markov Decision Processes, Approaches to the Synthesis for Markov Decision Problems.*
7. *Queueing Theory - Queueing Models, Performance and Dynamics of a Queuing System, Analysis of Markovian Queueing Systems, Markovian Queueing Networks, Control of Queueing Systems. (5h)*
8. *Discrete-Event Simulation - The Event Scheduling Simulation Scheme, The Process-Oriented Simulation Scheme, Simulation Languages, Output Analysis.*
9. *Sensitivity Analysis.*

Teaching methodologies (including evaluation):

- Short exposition of strategic nature for each one of the main chapters.
- Presentation of a number of themes by each one of the students followed by a discussion by the group.
- Challenging exercises to be addressed by the students.
- Discussion of the exercises so that studentes receive proper feedback to enhance their studying methods.
- Optionally the student might engage in a design project involving the topics above.
- Distributed Evaluation without final exam.

Main References

- *Christos G. Cassandras, Stéphane Lafortune; Introduction to discrete event systems.*
- *Y. C. Ho and X. R. Cao, Perturbation Analysis of Discrete Event Dynamic Systems, Kluwer Academic Publishers, 1991.*
- *P. Kozák and S. Balemi and R. Smedinga (eds.), Discrete Event Systems: Modelling and Control, Birkhäuser, Basel, Switzerland, 1993.*
- *R. Kumar and V. K. Garg, Modeling and Control of Logical Discrete Event Systems, Kluwer Academic Publishers, 1995, ISBN 0-7923-9538.*
- *Discrete Event Systems: Models and Application, Lecture Notes in Control and Information Sciences, Vol. 103, Springer Verlag, August 1987.*

Sistemas de Comunicações Móveis / Mobile Communications Systems

Professor: Manuel Alberto Pereira Ricardo

.Learning outcomes of the curricular unit:

Mobile Communications Systems has two main objectives: i) to provide students with the knowledge required to understand the current mobile communication systems, ii) to enable students to acquire the knowledge required to design the next-generation of mobile communications systems. At the end of UC students should be able to:

1. Describe and discuss the techniques used for data transmission over a wireless link;
2. Describe and discuss the techniques used to design communication networks made over wireless links;
3. Describe and discuss the techniques used to manage the mobility of mobile terminals;
4. Describe and discuss the techniques used in the design of secure mobile communications;
5. Describe and compare the mobile communications systems with respect to the architectures and techniques studied.
6. Set up and evaluate the operation / performance of prototypes of the techniques studied;
7. Discuss scenarios for the evolution of mobile communications.

Syllabus:

1. *Characteristics of a mobile communication system: applications of mobile communication systems; history of mobile communication systems; normalization organisms; reference models;frequency allocation.*
2. *Wireless transmission: models of signal propagation; modulations; codifications; adaptative techniques.*
3. *Wireless data links: multiplexing, duplex, ARQ, multiple access techniques, duplex; radio link control.*
4. *Networks over wireless links and network architectures: review of important concepts, MIPv6; reference models and architectures for radio access networks.*
5. *Wireless IEEE networks:802.11(WLAN),802.15(WPAN),802.16(WMAN).*
6. *Wireless mesh networks.*
7. *Wireless telecommunication networks: GSM, GPRS, UMTS and LTE.*
8. *Mobility management: models; case studies of 3GPP, IEEE and IETF networks.*
9. *Security in wireless networks: authentication models, encryption and access control; case studies of 3GPP and IEEE networks.*
10. *Quality of service and radio resource management*

Teaching methodologies (including evaluation):

Classes will be used by the students to get familiar with the themes of the course unit and materials to study and also to be acquainted with aspects related to the design of wireless communication networks. Distributed evaluation with final exam.

Main References

- *Schiller, Jochen H.; Mobile communications.. ISBN: 0-321-12381-6*
- *Mobile communications. ISBN: 0-321-12381-6*
- *Goldsmith, Andrea; Wireless communications. ISBN: 0-521-83716-2*
- *Glisic, Savo G.; Advanced Wireless Networks. ISBN: 13-978-0-470-01593-3*
- *Theodore Rappaport; Wireless Communications: Principles and Practice, 2nd Edition, Prentice Hall, 2001. ISBN: 0130422320*
- *Harri Holma, Antti Toskala; WCDMA for UMTS: HSPA Evolution and LTE, 5th Edition, John Wiley and Sons Lda, 2010. ISBN: 978-0-470-68646-1*
- *Wireless Mesh Networks; Ian Akyildiz, Xudong Wang, John Wiley& Sons, 2009. ISBN: 9780470032565*

Sistemas Embarcados em Tempo Real / Embedded Real-Time Systems

Professor: Luis Miguel Pinho de Almeida; Markus Ernst Petters

Learning outcomes of the curricular unit:

The objective of this course is to provide in-depth knowledge of the state of the art in the areas of Real-Time Scheduling and Real-Time Operating Systems (RTOSs), after a brief introduction to Specification and Modeling of Real-Time Systems. The competences to be acquired by the students are:

- Ability to search for related information in the field of Real-Time Systems scientific research
- Understanding of the specific features of RTOSs and capacity to classify them
- Ability to identify the situations in which RTOSs are particularly useful
- Capacity to relate and use the most common tools for specification and modeling of RT systems
- Ability to select adequate RT scheduling criteria and apply the associated timing analysis

The expected results are that the students acquire the competences referred above and become capable of identifying open research issues in the current state of the art in RTS research.

Syllabus:

1 - Introduction to Real-Time Embedded Systems

2- Brief Overview of Formal Specification and Modeling

- *2.1- Modeling and Analysis of Real-Time and Embedded systems (MARTE)*
- *2.2- Communicating Sequential Processes (CSP)*
- *2.3- Timed automata*

3- Real-time scheduling

- *3.1- The recurrent task model and constraints*
- *3.2- Periodic task scheduling*
- *3.3- Accessing shared resources*
- *3.4- Aperiodic task scheduling*

4- Real-time operating systems

- *4.1- OS/RTOS basics*
- *4.2- Approaches*
- *4.3- Inter process communication*
- *4.4- Concurrency*
- *4.5- Memory management*
- *4.6- Multiprocessor issues*

Teaching methodologies (including evaluation):

The course will be essentially based on lecturing plus seminars in which the students will be asked to search for recent research papers in given topics and present them to the class. The lectures will follow an interactive style.

Distributed evaluation without final exam.

Main References

- *Giorgio C. Buttazzo; Hard real-time computing systems. ISBN: 0-387-23137-4 Andrew S. Tanenbaum; Modern operating systems. ISBN: 0-13-813459-6*

Sistemas Embarcados Ubíquos / Ubiquitous Embedded Systems

Professor: Mário Jorge Andrade Ferreira Alves; Kumar Shashi Prabh

Learning outcomes of the curricular unit:

To acquire fundamental knowledge about ubiquitous embedded systems and wireless sensor/actuator networks (WSNs), namely on networking and sensor data collection and processing aspects, as well as on technological, systems and engineering aspects.

At the end of the course, the student should hold a general knowledge on UES and WSNs, namely on the state-of-the-art and emerging trends on network protocols and architectures, HW/SW platforms, quality-of-service, data aggregation and dissemination, complete system architectures and applications.

Syllabus:

- *Wireless sensor networks as infrastructures for UES*
- *Hardware and software platforms*
- *Network architectures*
- *Physical Layer aspects (link quality estimation, energy harvesting)*
- *Data Link Layer aspects (MAC+LLC)*
- *Network Layer aspects (topology discovery, management and control; routing, time synchronization, naming and addressing)*
- *Quality-of-Service (e.g. timeliness, scalability)*
- *Localization (localization, positioning, tracking)*
- *Data aggregation and dissemination*
- *Data-Centric Networking*
- *Sensing Capacity and Performance Analysis*

Teaching methodologies (including evaluation):

Oral presentations on the program topics, recurring to case studies. Seminars from invited experts in the field. Presentation (by students) and class discussion of seminal publications on the topics. Presentation (by each student/group) of a class project in a related topic.

Assessment has 2 components:

-WEEKLY ASSIGNMENT(30%):Read/analyze the proposed material for the incoming lecture, where a discussion may be held. A summary/write-up may be requested (must be a critique of the material - rather than a rewriting of it).

-CLASS PROJECT(70%):Each student (teams of 2 students may be exceptionally accepted) will work on a project during the entire semester. The project,whose topic can be proposed by the students, should include an overview of the state-of-the-art, a detailed technical description of the outcome, preferably with some scientific/technical contribution, e.g. based on analytical, simulation or experimental work. Grading will be based on written report, presentation and defense.

Main References

- *H. Karl, A. Willig, "Protocols and Architectures for Wireless Sensor Networks", Wiley-Interscience, October 2007. ISBN: 978-0-470-09510-2 (slides available at http://www.wiley.com/go/wsn)*
- *P. Marron, S. Karnouskos, D. Minder and the CONET consortium, "Cooperating Objects Roadmap – 2009", 1st edition, Logos Verlag, 2009. ISBN 978-92-79-12046-6 (PDF version available upon request or at http://www.cooperating-objects.eu/roadmap/download)*
- *Zhao, F., Guibas, L., "Wireless Sensor Networks: An Information Processing Approach", Elsevier, 2004. ISBN ISBN: 978-1558609143.*
- *K. Sohraby, D. Minoli, T. Znati, "Wireless Sensor Networks: Technology, Protocols, and Applications", Wiley-Interscience, May 2007. ISBN: 978-0-471-74300-2*

Sistemas Lineares / Linear Systems

Professors: Fernando Lobo Pereira and Paula Rocha Malonek

Learning outcomes of the curricular unit:

This course aims at providing the students with advanced skills and the underlying geometric insight for the analysis and synthesis of linear multivariable systems.

Syllabus:

- *Introduction*
- *Review of basic Algebraic concepts and vector spaces.*
- *Dynamics of time-varying and time-invariant systems*
- *Temporal response*
- *Stability*
- *Controllability and observability*
- *Realization Theory*
- *Linear state feedback and estimation*
- *Dynamic Feedback*
- *Linear quadratic control*

Teaching methodologies (including evaluation):

Lectures on the course material

Homework assignments

Evaluation: based on homework assignments and a final exam.

Main References

- *Frank M. Callier and Charles M. Desoer - Linear Systems Theory, Springer*

Tecnologias de Microeletrónica e Microeletromecânica / Microelectronic and Microelectromechanical Technologies

Professor: Vitor Manuel Grade Tavares; Luís Alexandre Machado da Rocha

Learning outcomes of the curricular unit:

To develop the background knowledge necessary to understand the state-of-the-art of semiconductor and Micro-Electro Mechanical Systems (MEMS) technologies, as well as the issues of integrating mechanical elements and electronics. A comprehensive, semester-long project is assigned, comprising the design of a sensor and the electronic front-end. This process requires the understanding of analogue design techniques as well as the basic design-flow used in the fabrication of MEMS devices, providing the integrated view of a MEMS-based sensor and analog front-end design. The basic concepts and circuits, for global noise reduction and interface between MEM-analogue and digital worlds, both at the circuit level and design methodologies, are also addressed for the understanding of the fundamental aspects associated with full system integration.

Syllabus:

MEMS Design:

- *-Introduction to MEMS: Main physical concepts: piezoresistivity, piezoelectricity, capacitive transduction.*
- *-Silicon mechanical properties.*
- *-Design rules.*
- *-Devices basics: Inertial and pressure sensors.*
- *-Modeling of MEMS.*
- *-Damping in MEMS.*

CMOS Design:

- *-MOS Model and higher order effects.*
- *-Technology rules and layout.*
- *-Basic Analog Cells - Introduction.*
- *-Fully differential amplifiers.*
- *-CMFB & CMFF.*
- *-High-bandwidth amplifiers.*
- *-Noise sources in analog and mixed signal circuits and analysis.*
- *-Capacitive MEMS read-chain.*
- *-Switched Capacitor (SC) circuits, analysis and non-ideal effects.*
- *-Noise reduction in SC circuits: Full differential design, Correlated Double-sampling (CDS) and delayed switching.*
- *-SC charge amplifier.*
- *-A/D and D/A concept and signal conditioning*
- *-Filter specifications and approximations.*
- *-Filter synthesis.*
- *-A/D and D/A figures of merit.*
- *-Converter types with emphasis on Sigma-Delta.*

Teaching methodologies (including evaluation):

This course combines lecture and project work to provide students with a practical, hands-on approach to microelectronics and micro-electro-mechanical systems (MEMS) technologies and systems conception. The lecture classes will take about half of the direct contact time, and will cover three main modules: Microelectronic principles, MEMS sensors and actuators and Signal conditioning and interfacing. Distributed evaluation with final exam.

Main References

- *Allen, Phillip E.; CMOS analog circuit design. ISBN: 0-19-511644-5*
- *Baker, R. Jacob; CMOS circuit design, layout, and simulation. ISBN: 0-7803-3416-7*
- *Johns, David; Analog integrated circuit design. ISBN: 0-471-14448-7*
- *S. D. Senturia; Microsystems Design*
- *Behzad Razavi; Design of Analog CMOS Integrated Circuits*

Teste e Projeto para a Testabilidade / Test and Design for Testability

Professor: José Alberto Peixoto Machado da Silva

Learning outcomes of the curricular unit:

This curricular unit will enable students to

1- Know the defects and the models used to analyse and simulate their effects, namely for test pattern generation purposes
2- understand the concepts of observability, controllability, and testability, and the algorithms used to compute these parameters
3- understand the difficulties raised by the access to testing nodes and the necessity for using self-test and electronic access techniques to facilitate the implementation of testing operations
4- know in detail the 1149.x standard test infrastructures and different digital and analogue test methodologies based on them

Syllabus:

Module I: Rationale and Testing Economics

1- Testing and test equipment
2- Test economics and product quality
3- Fault models, fault simulation and test vector generation

Module II: Digital design for testability

1- From scan design to boundary-scan testing
2- Digital extensions to the IEEE 1149.1 standard
3- Register-transfer level testability analysis and improvement
4- Fault-tolerant design within FPGAs

Module III: Memory testing

1- Memory architecture and defect trends
2- Fault modeling
3- Test pattern generation algorithms

Module IV: Analog and mixed-signal design for testability

1- Digital x analog testing worlds
2- The IEEE1149.4 standard for a mixed-signal test bus
3- Structural and parametric testing in mixed-signal circuits
4- Built-In Self-Test of analog and mixed-signal circuits

Teaching methodologies (including evaluation):

The adopted methodology involves tutorial presentation by the teacher and complementary study by the students. For each topic, after a preliminary introduction by the teacher, relevant bibliography is recommended which the students should study and from which write a text in a paper format or prepare an oral presentation to be delivered in the classroom. Additionally, students develop competences of project, implementation and evaluation of a testing methodology. A small project is assigned for each module to be developed individually or in groups of two. Student evaluation comprises the following components: Assignments: A; Projects: P; Midterm Exam: ME; Final Exam: FE The final score will be calculated according to the following rule: 30%×A+30%×P+20%×ME+20%×FE

Main References

- *Michael L. Bushnell, Vishwani D. Agrawal; Essentials of electronic testing for digital memory and mixed-signal VLSI circuits. ISBN: 0-7923-7991-8*
- *Laung-Terng Wang, Cheng-Wen Wu, Xiaoqing Wen; VLSI Test Principles and Architectures: Design for Testability , Morgan Kaufmann, 2006. ISBN: 0123705975*

2nd Semester

Computação em Grelha / Grid Computing

Professor: António Miguel Pontes Pimenta Monteiro

Learning outcomes of the curricular unit:

The main objectives are to provide the students with a solid knowledge of parallel computing (in clusters) and distributed computing in the Internet infrastructure, mainly Grid Computing and Cloud Computing. Also we can enlist as objectives to obtain a solid knowledge on parallel architectures and on developing parallel programs for distributed memory and shared memory architectures. Through assignments and lab projects the students will also obtain experience in the core technologies in the field, including performance analysis and tuning.

Syllabus:

*1. **Parallel Programming** - Introduction to parallel programming, computer architectures, processors, memory organization and interconnection networks. Parallel Programming Fundamentals: task/channel paradigm, communication patters, synchronization, task granularity and scheduling. Cluster programming with MPI and OpenMP. Parallel computing characterization: execution models, programming models, computation models, performance and efficiency measures, scalability analysis.*

*2. **Distributed Computing** - Grid computing - Grid computing models: generic grid, utility grid and desktop grid. Evolution of grid middleware: metacomputing (e.g. Condor), resource-oriented (e.g. Globus 3) and service-oriented (e.g. Globus 4). Grid security: authentication, data integrity and encryption, authorization. Hands-on Grid technology. Other distributed environments: Cloud Computing; Peer-to-Peer Computing*

Teaching methodologies (including evaluation):

In the Classes: Theoretical presentation, complemented by examples, small demonstrations and clues for lab assignments and project.

In the Labs: discussions, demonstrations and problem solving related to assignments and project.

Distributed evaluation without final exam (Final Grade = 50% Assignment + 50% Monography)

Main References

- *Quinn, Michael J.; Parallel programming in C with MPI and openMP. ISBN: 007-123265-6*
- *George Reese; Cloud Application Architectures, O'Reilly, 2009. ISBN: 978-0-596-15636-7*
- *Foster, Ian 340; The Grid. ISBN: 1-55860-475-8*
- *Vladimir Silva; Grid Computing for Developers, Thomson Delmar Learning, 2006. ISBN: 1-58450-424-2*
  Borja Sotomayor, Lisa Childers; Globus Toolkit 4. ISBN: 0-12-369404-3

Controlo Não Linear / Non Linear Control

Professors: Fernando Manuel Ferreira Lobo Pereira; Maria do Rosário Marques Fernandes Teixeira de Pinho

Learning outcomes of the curricular unit:

Present and discuss the main concepts and results of the state-of-the-art in the control of nonlinear systems. Design controllers for nonlinear systems that satisfy given classes of requirements.

Syllabus:

Background

Lyapunov Stability

Input-Output Stability

Analysis of Feedback Systems

Feedback Control

Feedback Linearization

Lyapunov Based Design

Teaching methodologies (including evaluation):

Classes and Project based learning.

Distributed evaluation without final exam.

Formula for calculating the final grade: Homework (40%) + Project (60%)

Main References

- *Hassan K. Khalil; Nonlinear systems. ISBN: 0-13-067389-7*
  Jean-Jacques E. Slotine, Weiping Li; Applied nonlinear control. ISBN: 0-13-040890-5

Gestão e Controlo de Redes / Network Management and Control

Professor: Ricardo Santos Morla

Learning outcomes of the curricular unit:

This course is intended for students who are interested in the management and control of enterprise-level computer networks and in detecting and diagnosing anomalies in those networks. Enterprise networks typically include Petabit/s -scale network core, million user -scale fixed and wireless mesh access network, urban sensor networks, and complex network services such as video content distribution. The large scale of these networks, their intricate behavior, and the need to provide a quality service to high-end users makes it critical to adequately employ network abstraction and control techniques, as well as anomaly detection and diagnosis. The aim of this course is to introduce the main issues and technologies currently used in network management, to cover the fundamentals of anomaly detection and diagnosis techniques, and to illustrate the application of these techniques to the management of enterprise networks. A semester-long project will enable students to apply these concepts to real problems, potentially resulting in a publishable paper. Students will present their topics and related work in class throughout the semester.

Syllabus:

1. Introduction to network management. Enterprise networks and network infrastructure, network management systems, FCAPS.

2. Measurements. Control and data plane, passive vs. active measurements, traffic matrix, flow-level measurements.

3. SNMP. Manager, agents, protocol, and information base.

4. Anomaly detection and diagnosis in enterprise networks. Hardware and software anomalies, usage, flash crowd, hierarchical anomalies.

5. Anomaly detection techniques. Classification, clustering, statistical, information-theoretical, and spectral-based methods; online anomaly detection.

6. Diagnosis and fault location. Detection, location, and testing. Expert systems, fault propagation, code-book, bi-partite causality graphs, belief networks.

7. Statistical modeling and learning of network data and relations. Mixture models and hidden Markov models; probabilistic graphical model framework, parameter and structure learning.

Teaching methodologies (including evaluation):

Students will have to prepare lectures on their own topics and work on the course project. Students are required do to a group project. This project will result in a presentation and a final report of publishable quality. Students are required to do paper reading for discussion in class, lecture-like presentation of papers related to the project, and mid-term project presentation and discussion. The components for student evaluation are: P – Semester-long project; CP – Class participation. Each component will receive a grading in percentage. The final score will be calculated according to the following rule: 80% * P + 20% * CP. Grading will be either PASS or FAIL. A PASSing grade corresponds to a minimum of 2/3 of the maximum score.

Main References

- *Automated Network Management Systems, Current and Future Capabilities. Douglas E. Comer. Pearson/Prentice Hall 2006*
- *Network Management – Principles and Practice. M. Subramanian. Addison-Wesley, 2000*
- *SNMP, SNMPv2, SNMPv3, and RMON 1 and 2 (3rd Edition). William Stallings. Addison-Wesley Professional, 1999*
- *The Elements of Statistical Learning. T. Hastie, R. Tibshirani, and J. Friedman, Springer-Verlag, 2001.*
- *Probabilistic Graphical Models: Principles and Techniques. D.Koller and N.Friedman, The MIT Press, 2009.*

Instrumentação e Teste de Sistemas / Instrumentation and Systems Testing

Professors: José Alberto Peixoto Machado da Silva; José Manuel Martins Ferreira

Learning outcomes of the curricular unit:

This cur. unit will enable students to: 1.understand the challenges raised :by accessing systems' test nodes; by propagating delicate test signals; by the implementation and packaging technologies; and to evaluate how they affect test implementation and results 2.understand the fundamentals of testing MEMS. 3.know different instrumentation and measurement systems architectures used in characterization, debug, and production testing of electronic products 4.apply different signal processing and statistical process control techniques and select appropriate product testing standards for quality assurance. Upon completion of the subject students will be able to:

- design and characterize a test and measurement system using bench-top or data-acquisition and signal generation instruments;
- evaluate the static and dynamic characteristics of test interconnections and interfaces
- design appropriate testing plans based on the features of a product and the standards required for its test.

Syllabus:

Trends in embedded systems and packaging

- *High-density packaging testing*
- *Modelling of interconnects and transmission lines; Signal propagation and integrity*
- *Defects, failures modes, and fault simulation in MEOMS; Design of MEOMS with self-test functions*

Embedded test and prototype debugging

- *The IEEE 1500 Standard for Embedded Core Test; Wrappers and Test Access Mechanism*
- *Techniques and tools for prototype debugging; NEXUS - Standard for a Global Embedded Processor Debug Interface*
- *Embedded instrumentation interface buses*

Instrumentation and automatic test equipment

- *DSP based testing and data analysis; Discrete time transforms and the inverse FFT; Data analysis and statistical process control*
- *Open architecture ATE vs. traditional ATE; The Open Semiconductor Test Architecture (OPENSTAR®) initiative*
- *Smart Instruments; High accuracy calibration.*

Teaching methodologies (including evaluation):

Preparation of a short monography and a presentation. This aims, on the one hand, to charge students more responsible for their own education, and on the other hand, promote the continuous update of the learned topics with new developments presented at conferences and in published journals. These two components of this work contribute for developing skills of bibliographic search, synthesis of the state of the art on a scientific domain, and written and oral presentation. Additionally, each student is assigned a lab project involving the implementation of a dedicated PC based test system that allows developing further some of the studied topics.

Computation of the final mark:40%× Assignments+40%×Projects+20%×Final Exam

Main References

- *Mark Burns, Gordon Roberts; An Introduction to Mixed-Signal IC Test and Measurement, Oxford University Press, 2001.*
- *Johnson, Howard W.; High-speed digital design. ISBN: 0-13-395724-1*
- *Dominique Dallet, José Machado da Silva; Dynamic Characterization of Analogue-Digital Converters, Springer, Kluwer Academic Publishers, 2005. ISBN: 0-387-25902-3 (HB), 0-387-25903-1*

Processos Estocáticos / Stochastic Processes

Professor: Fernando Arménio da Costa Castro e Fontes; Paulo Jorge de Azevedo Lopes dos Santos

Learning outcomes of the curricular unit:

To provide graduate students in the area of, control theory and other related disciplines with a solid background in random processes and in estimation, filtering and prediction theory. At the end of the course, it is expected that the students are able to:

- understand scientific literature in which stochastic processes, with discrete and with continuous sample spaces, are formally defined.

- Describe, in a formal and rigorous way, the stochastic processes used in specific applications.

- Know, understand and can apply the main methods studied for estimation, prediction and filtering.

Syllabus:

1 - Probability spaces
2 - Construction of probabilities spaces
3 - Measurable functions
4 - Integration and Expectation
5 - LQ Probability spaces
6 - Independence:
7 - The Fubini theorem.
8 - The Radon Nikodin derivative
9 - Random variables
10 - Random Vectors
11 - Useful Inequalities
12 - Convergence of random variables
13 - Random walk
14 - Filtrations
15 - Estimation and Prediction
16 - Kalman Filter
17- Stochastic Realization Theory

Teaching methodologies (including evaluation):

There will be expository lectures in the end of which a list of problems are proposed. Such lectures are followed by discussion classes to treat problems assigned on the subject. Distributed evaluation without final exam.

Main References

- *Katayama, Tohru 1942-; Subspace methods for system identification. ISBN: 1-85233-981-0*
- *Grigoriu, Mircea; Stochastic calculus. ISBN: 3-7643-4242-0*
- *J. F. C. Kingman , S. J. Taylor ; Introduction to Measure and Probability , Cambridge University Press, 2008. ISBN: ISBN-10: 0521090326 | ISBN-13: 978-0521090322*

Projeto Avançado de Sistemas de Microeletrónica / Advanced Microelectronic Systems Design

Professors: José Carlos dos Santos Alves; João Paulo de Castro Canas Ferreira

Learning outcomes of the curricular unit:

The objective of this course it to provide students with the background needed for the design and implementation of complex integrated electronic systems, starting from high-level abstract requirements and proceeding through successive refinement stages to a complete physical implementation in a modern, highly integrated, IC technology (e.g., sub-micron CMOS or platform FPGA). Students will acquire an understanding of the fundamental aspects of timing and quality issues involved in this task, and solid knowledge of how they influence the design decisions and methodologies.

Syllabus:

1 – System specification and modelling: Electronic System Level (ESL) design flows. Design modelling based on algorithmic descriptions (C/C++/SystemC). Design space exploration and system partitioning. Hardware/software co-design. Integration of IP (Intellectual Property) blocks. System and behavioural synthesis. Platform-specific design aspects.

2 – System integration and physical synthesis for cell-based ICs: Technology-driven partitioning. Floorplanning. Placement and routing. Post-layout verification.

3 – System timing and clock management: Delay models for digital circuits and interconnects. Clocking strategies. Clock signals. Synchronization, generation and distribution. Multiple clock domains. Dynamic clock management. Timing constraints for synthesis.

4 – Power-aware system design: Modelling power consumption in digital circuits. System-level power management. Tools and methodologies for power-aware design.

Teaching methodologies (including evaluation):

Lectures will be used to present and discuss the course topics.

Practical work will be based on a design project that will address the main topics of the course

All support material will be available on-line.

Distributed evaluation with final exam (Formula for calculating the final grade:Final grade (F) is given by:

F = 0.6 P + 0.4 E where P is the project grade and E is the final exam grade)

Main References

- *Michael Fingerhoff; High-level Synthesis Blue Book. ISBN: 978-1-4500-9724-6*
- *Scott Hauck; André DeHon; Reconfigurable Computing: The Theory and Practice of FPGA-Based Computation, Morgan Kaufmann, 2007*
- *De Micheli, Giovanni; Ernst, Rolf; Wolf, Wayne; Readings in Hardware/Software Co-Design, Morgan Kaufmann, 2002. ISBN: 9781558607026*

Reconhecimento e Análise de Imagem / Image Analysis and Recognition

Professor: Aurélio Joaquim de Castro Campilho

Learning outcomes of the curricular unit:

This graduate course on Image Analysis and Recognition aims to give the student the ability to understand and apply some of the recent advances in this rapid evolving field of Image Analysis and recognition. There is a text book together with a list of selected original research papers in order to allow the students to follow the advances in the addressed topics. The course main topics will allow the students to gain the competences in: image segmentation, tracking, Image registration and object and pattern recognition and matching. The course will discuss the use of the learned methods and techniques in applications such as visual inspection, document processing, biomedical and biometrics.

Learning outcomes: The course main topics will allow the students to gain the competences in: image segmentation, tracking, Image registration and object and pattern recognition and matching.

Syllabus:

1. Image Enhancement 2. From color to edges and textures 3. Segmentation a. Clustering methods. Embedding local constrains. Mean Shift c. Graph-theoretic clustering. Graphs. Affinity measures. Graph Cuts. 4. Motion analysis a. Background subtraction b. Optical flow c. Tracking using linear and non-linear dynamical models. 5. Image Registration a. Multi view geometry. b. Strategies for image registration of rigid and non-rigid objects. c. Local invariant features and similarity measures. 6. Image Recognition a. Machine learning tools b. Feature extraction and selection: i. Principal Component analysis. ii. Object and shape representation using invariant features. c. Object modeling i. Active appearance models. ii. Constellation model and the Implicit Shape Model. iii. Bag of visual term models. d. Recognition examples

Teaching methodologies (including evaluation):

The course is organized in a set of 28 lectures together with oral presentation and computer vision labs.

Distributed evaluation with final exam. (Formula for calculating the final grade: Grading and evaluation is based on the following scheme: Assignments: 30% (10% for each one of the 3 assignments) Presentation of a selected research paper: (10%) Project: 30% Final exam: 30% Grading will be from 0 to 20. A PASSing grade corresponds to a minimum of 10.

Main References

- *Forsyth and Ponce; Computer Vision. A Modern Approach,, Prentice Hall, 2002*

Robótica Móvel / Mobile Robotics

Professors: Paulo José Cerqueira Gomes da Costa

Learning outcomes of the curricular unit:

This graduate course on Mobile Robotics aims to give the student the ability to understand and apply its main concepts and the recent advances in this field.

There are three text books together with a list of selected original research papers that allow the students to follow the advances in the addressed topics. The course main topics are: Sensors and perception, Localization, Dynamic modeling, Trajectory generation, Motion control, Cooperation and multi-robot systems, Applications (soccer, indoors, outdoors, aerial, underwater, ...).

Syllabus:

1. Robot modeling

- *Kinematics.*
- *Dynamics.*
- *Velocity / Odometry motion model.*

2. Sensors and perception

- *Sensor models.*
- *Correlation-based measurement.*
- *Feature-based measurement.*

3. Localization

- *Local Versus Global Localization*
- *Passive and active approaches.*
- *Dynamic environments.*
- *Multiple Robots*

4. Navigation and trajectory generation

- *Configuration space.*
- *Potential fields.*
- *RoadMaps.*
- *Cell decompositions.*

5. Motion control

- *Feedback control.*
- *Non-linear control.*
- *Hierarchical systems.*

6. Cooperation and multi-robot systems

7. Applications (land robots: indoors, outdoors, roads; aerial, underwater,…)

Teaching methodologies (including evaluation):

Evaluation with final exam. Grading and evaluation is based on the following scheme:

Project: 80%

Project Presentation: (20%)

Grading will be from 0 to 20. A Passing grade corresponds to a minimum of 10.

Main References

- *Sebastian Thrun, Wolfram Burgard, Dieter Fox; Probabilistic robotics. ISBN: 0-262-20162-3 Howie Choset... [et al.]; Principles of robot motion. ISBN: 0-262-03327-5*

Simulação de Mercados / Market simulation

Professor: João Paulo Tomé Saraiva

Learning outcomes of the curricular unit:

The course on Markets and Simulation aims at analyzing the issues faced by firms, regulators and policy-makers in liberalized energy markets. This involves a comprehensive analysis of the characteristics, evolution and interactions among different energy and energy-related markets, that are relevant for their modeling and simulation and issues related with their physical and financial operation will also be addressed.

Market theory and market models will be described, providing a broad conceptual framework for market simulation. Several case studies will be presented coming from different perspectives: academic, system operator, market operator and market agent.

An important objective of this course is to contribute to develop the capacity of the students to work autonomously, to do bibliographic research, to prepare written reports and to deliver oral presentations.

Syllabus:

1- *Description of different energy and energy-related markets;*
2- *Different purposes and ways for energy market analysis;*
3- *Requirements and difficulties of energy market simulation;*
4- *Different market theories and models;*
5- *Description of several market simulation tools;*
6- *Simulation of electricity markets in several European countries;*
7- *Simulation of coupled electricity markets with limited interconnection capacity;*
8- *Basic description of financial tools and respective markets;*
9- *Use of financial tools in energy markets – Case Studies;*
10- *Investment, Risk and Regulation in Power Markets;*
11- *Brief description of carbon markets;*
12- *Impact of information and communication technologies on energy markets;*
13- *Impact of the demand participation in energy markets and the challenges to traditional simulation approaches.*

Teaching methodologies (including evaluation):

According to the indications of the PDEEC Plan of Studies, the classes of the course on Market Simulation are used to expose the topics of the program and to present and discuss illustrative examples. These classes will use power point files that will be made available to the students as complementary studying material. Along the classes several case studies will be discussed in order to highlight specific topics to be addressed. Finally, the students will present the results obtained in the assignments they are asked to complete along the course and they will deliver a specific presentation regarding a topic they select in the scope of the course. This oral presentation corresponds to a specific assignment and has a weight of 10% in the final grade. Distributed evaluation with final exam. The components to be considered in the evaluation of the students are:

- Assignments
- Final exam

Main References

- *J.-M. Glachant, F. Lévêque; Electricity reform in Europe. Towards a Single Energy Market, 2009*
- *Edward Elgar; Competitive Electricity Markets and Sustainability, F. Lévêque, 2006*
- *D. M. Newbery; Privatization, Restructuring and Regulation of Network Utilities, 1999*
- *B. Mandelbrot, R. L. Hudson; The (mis)behavior of markets, 2004*
- *P. Pereira da Silva; O sector da energia eléctrica na União Europeia, Imprensa da Universidade de Coimbra, 2007*

Sistemas de Comunicações Óticos Avançados / Advanced Optical Communications Systems

Professor: Henrique Manuel de Castro Faria

Learning outcomes of the curricular unit:

This course aims to present the state of the art in optical communication systems, either digital or analog, presenting the fundamental concepts needed for system design. Emphasis will be given to high bit-rate systems with optical amplification and next-generation optical networks (networks of transport and access), presenting technological solutions to overcome the current limitations of fiber and devices.

- Understanding the specific characteristics of the optical fiber transmission systems, its advantages and limitations.
- Knowledge of project-oriented optical communication systems
- Ability to search for information on research in advanced optical systems and networks for future generation
- Capacity Analysis, simulation and design of such systems Learning outcomes are acquiring the skills oriented to the project as well as the ability to identify relevant topics for research in networks *and next generation optical systems.*

Syllabus:

Optical amplifiers
Semiconductor amplifiers, EDFA.
Erbium doped fiber amplifier (EDFA): analysis of gain, saturation and noise; applications.
Analysis of preamplified optical receivers; systems with chains EDFA amplifiers.
Raman amplification, amplification versus localized distributed amplification.
Dispersion and nonlinear effects.
Analysis of the impulse propagation in fiber and interaction between the dispersion and nonlinear effects.
Propagation of solitons.
Management of dispersion in optical systems.
Multichannel systems and optical networks multiaccess
Components and WDM systems.
Devices and multiaccess topologies.
Distribution of radio-frequency and microwave signals over fiber optics.
Networks passive optical access network.
Advanced optical systems and high speed
Modulation Formats: duo-binary PSK, QAM
- Polarization Division Multiplexing
- Spectral Efficiency
- Comparison of coherent and non-coherent detection techniques.

Teaching methodologies (including evaluation):

Classes will be used for exposition of course topics and for the presentation of research papers by students. During classes, students will conduct simulation studies based on commercial software.
Distributed evaluation with final exam.
The assessment of the course comprises the following elements:
- (O) Oral presentation of selected articles
- (R) Reports of practical simulation works
- (M) Monograph on a topic of concerned with the course subject
- - (E) Final Exam

Final rating: 15%×O+15%×R+30%×M+40%×E

Main References

- *Govind P. Agrawal; Fiber-optic communication systems. ISBN: 0-471-21571-6*
- *Govind P. Agrawal.; Nonlinear fiber optics. ISBN: 0120451433 (acid-free paper)*

Sistemas de Desenvolvimento de Hardware/Software / Hardware/Software System Development

Professors: João Manuel Paiva Cardoso; José Carlos dos Santos Alves

Learning outcomes of the curricular unit:

To learn about the processes, methodologies, techniques, and best practices associated to development of hardware/software systems

To acquire the capability to analyze and evaluate the performance of a real-life computing application and to conceive and develop a hardware/software system capable of improving its performance on a conventional computing system.

Syllabus:

Heterogeneous multi-core system design:

1. Systems-on-Chip (SoC) and reconfigurable platforms
2. General purpose and application-specific cores
3. Customizable embedded processors
4. Performance-driven partitioning
5. Interprocessor communication infrastructures
6. Industrial design flows: methodologies and tools
System level modelling, verification and synthesis:

1. Electronic system level (ESL) design methodologies
2. Unified hardware/software verification
3. Hardware emulation
4. Transaction-level modelling
5. Model refinement
6. High-level hardware synthesis
7. Micro-architecture design
Mapping Techniques for Hardware/Software Systems:

1. From Software to Application-Specific Architectures;
2. Software synthesis and code generation;
3. Hardware/Software Partitioning;
4. Compiler Optimizations and Loop Transformations
5. Hardware/Software Estimation Techniques;
6. Design Space Exploration Techniques

Teaching methodologies (including evaluation):

The weekly classes include lectures, presentations by the students about themes developed during the study and analysis of a scientific paper and presentation and discussion of the practical projects. The work developed by the students is divided into the analysis and discussion of a set of scientific papers (one per student) focused in selected course topics, and in the development and presentation of a project focused on designing hardware/software systems with high-level synthesis. Distributed evaluation without final exam.

Main References

- *Philippe Coussy, Adam Morawiec; High-Level Synthesis From Algorithm to Digital Circuit: From Algorithm to Digital Circuit, Springer Science + Business Media B.V, 2008. ISBN: 1402085877*
- *Michael Fingeroff; High-Level Synthesis Blue Book, Mentor Graphics Corporation, 2010. ISBN: 1450097243*

Sistemas Eletrónicos de Potência / Power Electronic Systems

Professor: Adriano da Silva Carvalho

Learning outcomes of the curricular unit:

To apply the knowledge, methods and tools got within previous programme - Energy Conversion in main application domains. The student must be able of choosing the appropriate power converter from functional and technical requirements put by the application as well as to design the whole system.

Syllabus:

Fundamentals of renewable energy sources: wind energy, solar/photovoltaic energy, fuel cell and biomass. Modeling for power electronics conditioning. First stage conversion: form primary energy source to electrical one.

Fundamentals of electrical traction: electrical vehicles and trains. Modeling of mechanical loads for electrical circuits. Energy recovery. First stage conversion: form primary energy load to electrical energy.

Power electronics conditioning: voltage and current sources. Analysis of requirements for converter design.

Control methods considering the energy source/load characteristics: algorithms for maximum power flow. Analysis of converter control methods satisfying system requirements.

Dynamical and permanent faults. Operation under abnormal conditions. Safe operation of global system. Standardization.

High performance and dynamics analysis by simulation of power electronics converters based systems using MatLab, SaberTM and PSIM software packages.

Teaching methodologies (including evaluation):

Classes will include lectures, involving computer simulation and oral presentations by the students reporting conclusions from their oriented study and research in specific domains.

Distributed evaluation with final exam.

The components for student evaluation are:

- Assignments
- Projects
- Exam

Each component will receive a grading in percentage.

The final score will be calculated according to the following rule:

0.2 * Assignments + 0.4 * Projects+0.4 * Exam

A Passing grade corresponds to a minimum of 2/3 of the maximum score.

Main References

- *T. Ackermann; Wind Power in Power Systems, John Wiley and Sons, 2005*
- *M. R. Patel; Wind and Solar Power Systems, CRC Press, 1999*
- *R. O'Hayre, S.-W. Cha, F. B. Prinz, W. Colella; Fuel Cell Fundamentals, John Wiley & Sons, 2005*
- *Mehrdad Ehsani , Ali Emadi , and John M . Miller; Vehicular Electric Power Systems, CRC Press, **2003***

Sistemas Embarcados Paralelos e Distribuídos / Parallel and Distributed Embedded Systems

Professors: Eduardo Manuel Medicis Tovar; Pedro Alexandre Guimarães Lobo Ferreira do Souto

Learning outcomes of the curricular unit:

The objective is to enable the students to perform a worst-case timing analysis of distributed embedded systems (e.g., embedded sensor actuator networks with medium access control and bus contention) and parallel embedded systems (platforms with multiprocessors or manycores).

Syllabus:

Multiprocessor Scheduling with Implicit-Deadline Tasks with Periodic and Sporadic Arrival: Models; Partitioned scheduling; Global Scheduling, RM-US(m/3m-2), PFair and Hybrid/semi-partitioned scheduling.

Models of distributed computation. The synchronous round model. Distributed consensus in synchronous systems. Logical time, Lamport timestamps and the ordering of events. Fault-tolerant broadcasts. The state machine approach for implementing fault-tolerant services.

Worst-case queuing and end-to-end delay analysis in distributed embedded networks. Response time analysis (RTA) for TDMA-based, CAN-like and producer-distributed consumer (multi-cycle scheduling) MAC models. Timed-Petri Nets.

Teaching methodologies (including evaluation):

Lectures are used to present and discuss the subject matter. Reading assignments are used so that students are exposed to current research. An optional project can be used by the students to get a deeper understanding in one particular subject.

Type of evaluation: Distributed evaluation with final exam

Terms of frequency: Minimum of 40% in the average of the best 6 of 9 quizzes.

Formula Evaluation: 0,5Q+0,5P

Q- average of best 6 of 9 quizzes (closed book, about 20 min)

P - Project/Final Exam

Main References

- *J. Carpenter, S. Funk, P. Holman, J. Anderson and S. Baruah; Scheduling Algorithms, Methods and Models., Chapman Hall/CRC, 2004*
- *J. López, J. L. Díaz, D. García; Utilization Bounds for EDF Scheduling on Real-Time Multiprocessor Systems, Kluwer, 2004*
- *S. Baruah, A. Mok, L. Rosier; Preemptively Scheduling Hard-Real-Time Sporadic Tasks on One Processor, IEEE CS, 1990*
- *Neil C. Audsley; On priority assignment in fixed priority scheduling, 2001*
- *S. Baruah, N. Cohen, C. Plaxton, D. Varvel; Proportionate progress: A notion of fairness in resource allocation, 1993*
- *N. Lynch; Distributed Algorithms, Morgan Kaufmann, 1996.*
- *ed. Sape Mullender; Distributed systems. ISBN: 0-201-62427-3*
- *Edudardo Tovar; Supporting Real-Time Communications with Stnadard Factory-Floor Networks, Ph.D. Thesis, Univ. Porto, 1999*
- *G. Rozenburg, J. Engelfriet. Elementary Net Systems. W. Reisig, G. Rozenberg (Eds.); Lectures on Petri Nets I: Basic Models - Advances in Petri Nets, Vol. LNCS 1491, Springer, 1998*

Sistemas Híbridos / Hybrid Systems

Professors: Fernando Manuel Ferreira Lobo Pereira; João Tasso de Figueiredo Borges de Sousa

Learning outcomes of the curricular unit:

Knowledge and competences pertinent to the analysis of hybrid systems – systems whose dynamics are simultaneously time-driven and event-driven – as well as to the control synthesis. Acquisition of the scientific basis to handle - modeling, analysis, control synthesis and optimization - hybrid systems. Mastering of the underlying methods and tools.

Syllabus:

1. Introduction and motivation
2. State machines and their composition.
3. Basic concepts and results of linear, non-linear and switched systems.
4. Hybrid systems modeling
    4.1 Articulation of event-driven and time-driven dynamics.
    4.2 Classes of models.
    4.3 Timed autamata
    4.4 General formal model
    4.6 Simulation of hybrid systems
    4.7 Mini-project on hybrid systems modeling using MATLAB and StateFlow
5. Control design
    5.1 Supervisory control
    5.2 Reachability and safety problems
    5.3 Behaviors and requirements specification
    5.4 Control synthesis techniques
    5.5. Exercises and mini-project on hybrid systems control synthesis using the MALAB toolbox.

Teaching methodologies (including evaluation):

Short exposition of strategic nature for each one of the main chapters.

Presentation of a number of themes by each one of the students followed by a discussion by the group.

Discussion of the exercises so that students receive proper feedback to enhance their studying methods.

Distributed evaluation without final exam.

Final grade calculus formula:

Average of the grades given to the exercises in the class and at home has a 40% weight.

Performance in the presentation and technical discussion of the work has a 60% weight.

Main References

- *John Lygeros, Claire Tomlin, Shankar Sastry, Hybrid Systems: Modeling, Analysis and Control,Dec 28, 2008 (Lecture Notes)*

Sistemas renováveis / Systems with renewables

Professor: João Abel Peças Lopes

Learning outcomes of the curricular unit:

- Be familiar with different energy conversion systems that exploit renewable power sources (hydro, PV, wind, wave energies).
- Be familiar with the control techniques used namely in PV and wind generation. Obtain a deep view of the existing control techniques used in wind energy conversion systems.
- Be capable of identifying the main problems for operation and expansion of electric power systems resulting from a large scale integration of renewable power sources.
- Be capable of understanding the needs for protection coordination in power systems new energy conversion systems.
- Be familiar with different micro-generation technologies and its dynamic models for dynamic stability studies.
- Understanding MicroGrid operation, management and control strategies for islanded and grid-connected operation.
- Be familiar with microgrid and micro-generators protections.
- Understand the need for SmarGrids developments.

Syllabus:

- *Modelling of induction generators, double fed induction machines, variable speed electronically interfaced units.*
- *Impacts of renewable energy conversion systems on power quality (Voltage deeps, Harmonic, Flicker); Integration limits regarding grid voltage stability and dynamic behaviour; Ride through faults and FACTS. Wind generators delivering voltage and frequency control and damping electromechanical oscillations.*
- *PV systems: fundamentals, equivalent circuits, operation points. Sizing PV systems.*
- *Grid code, hierarchical control structures.*
- *Remuneration of renewable energy systems (feed-in tariffs, quota system, price premium, investment grant, tax reimbursement, bidding); Participation of in markets (ancillary services markets); Combined wind generation / storage.*
- *Microgeneration and microgrids: technologies, concept, architecture, operating modes. Power electronic interfaces.*
- *Islanded operation. Service restoration. Multi-microgrids*
- *Integration of EV.*

Teaching methodologies (including evaluation):

Classes will include lectures, labs (exploiting simulation software) and oral presentations from students reporting conclusions from their oriented study and research in specific domains.

Distributed evaluation with final exam. The components for student evaluation are:

- Assignments
- Exam

Each component will receive a grading in percentage. The final score will be calculated according to the following rule: 0,5 * Exam + 0,5 Assignments. At least two assignments will be asked one related with dimensioning of PV systems and the other involving a short paper on important issues related with the development of the electrical grids of the future namely when dealing with the integration of renewable energy sources.

Main References

- *Edited by Tom Markvart and Luis Castaner.; Practical handbook of photovoltaics :. ISBN: 1856173909*
- *J. F. Manwell, J. G. McGowan and A. L. Rogers; Wind energy explained. ISBN: 0-471-49972-2*

Software Fiável e Concorrente/Reliable and Concurrent Software

Professors: Mário Jorge Rodrigues de Sousa; Luis Miguel Rosário da Silva Pinho

Learning outcomes of the curricular unit:

Guaranteeing the correct specification and behavior of concurrent/parallel software needs the integration of several aspects in its development, from the software development process, to the tools (languages, operating systems, compilers, …) used for its development.

This course will therefore present selected topics for the correct development of concurrent and parallel software. Upon completion of this course, students should be able to understand and apply processes, methods, and tools to implement software solutions to parallel, real-time embedded systems' problems.

Syllabus:

Software Reliability

- Basic Concepts and Taxonomy (Dependability, reliability, fault tolerance, ...)

- Development of Safety-Critical Software (Hazard and risk analysis, relevant standards)

- Methods of obtaining dependable software (Prevention and Fault Tolerance)

- Methods of verifying and validating software dependability

Concurrency

- Concurrent programming: limitations of common models

- Specific/appropriate languages for real-time and embedded systems (Java, Ada, Erlang, ...)

- Restricting concurrency

- Multiprocessor concurrency issues

Teaching methodologies (including evaluation):

The course will be essentially based on lecturing plus potentially invited seminar(s) in particular topic(s). The lectures will follow an interactive style.

Distributed evaluation without final exam (The students will be required to complete three seminars, where they will each discuss a selected paper.)

Main References

- *Storey, Neil; Safety-critical computer systems. ISBN: 0-201-42787-7*
- *Algirdas Avizienis, Jean-Claude Laprie, Basic Concepts and Taxonomy of Dependable and Secure Computing, IEEE TRANSACTIONS ON DEPENDABLE AND SECURE COMPUTING, VOL. 1, NO. 1, JANUARY-MARCH 2004*
- *IEC 61508: Functional Safety of Electrical/Electronic/Programmable Electronic Safety-related Systems (E/E/PE, or E/E/PES).*
- *Burns, A., Wellings, A., □ Real-Time Systems and Programming Languages (Fourth Edition) - Ada 2005, Real-Time Java and C/Real-Time POSIX□, Addison Wesley, 2009.*
- *Ben-Ari, M., "Principles of Concurrent and Distributed Programming", 2nd Edition, Addison-Wesley, 2006.*

Técnicas de Otimização / Optimization Techniques

Professors: Maria Antónia da Silva Lopes de Carravilla; Maria Cristina de Carvalho Alves Ribeiro

Learning outcomes of the curricular unit:

The main objective of this course is to build skills for creating models for combinatorial optimization problems and to solve them through exact techniques. It is expected to endow the students with skills to:

- Identify, analyse and structure optimization problems;
- Build models for optimization problems;
- Obtain solutions for continuous linear optimization problems using the simplex method and duality theory;
- Analyse the robustness of continuous linear optimization problems solutions using sensitivity analysis;
- Build solutions for mixed integer and binary optimization problems using tree-search algorithms;
- Use decomposition techniques to solve hard optimization problems;
- Identify the best techniques to solve a particular problem;
- Use CPLEX through OPL Studio interface to solve optimization problems and get insights on the solutions;
- Use ILOG Solver to solve constraint programming models for combinatorial problems.

Syllabus:

(2 x 3 hours) Mathematical Programming; Linear programing formulations for continuous linear optimization problems; Geometrical analysis of optimization problems.

(1 x 3 hours) Solving Linear Programs, the Simplex Algorithm.

(1 x 3 hours) Sensitivity analysis.

(1 x 3 hours) Duality in Linear Programming.

(1 x 3 hours) Integer Programming (Branch-and-Bound).

(2 x 3 hours) Using IBM ILOG CPLEX Optimization Studio.

(5 x 3 hours) Constraint Programming.

Teaching methodologies (including evaluation):

Before each one of the classes the students should study the corresponding chapter in the book

Each class will start with a quiz on the book chapter discussed in the previous class. The new chapter will then be presented and some exercises, will be solved in class.

The learning process will be consolidated through two group assignments that will be based on the use of software for solving linear problems (CPLEX) and programming problems with constraints (ILOG Solver).

Distributed evaluation without final exam. The final score will be calculated according to the following:

- 5 quizzes (5 x 10%)
- 2 group assignments (20% + 30%)

Main References

- *IBM ILOG CPLEX Optimization Studio (available on-line)*
- *Bradley, Hax, and Magnanti; Applied Mathematical Programming, Addison-Wesley, 1977 (downloadable from http://web.mit.edu/15.053/www/)*
- *Kim Marriott and Peter J. Stuckey; Programming with constraints. ISBN: 0-262-13341-5*

Teoria da Informação / Information Theory

Professor: Jaime dos Santos Cardoso

Learning outcomes of the curricular unit:

Objective: expose students to the fundamental elements and practices of information theory(IT), covering both theoretical and applied is- sues of recognized importance in contemporary communications systems and networks. The first part covers the basic principles of IT, such as source and channel coding for single-user(point-to-point) and multi-user communications systems. The second part covers advanced applications of IT, including the analysis, design and optimization of wireless communications systems and networks, sensor networks and network information flow, as well as security and privacy.

Learning outcomes: Familiarity with the principles and applications of information theory in wireless systems and networks, sensor networks, network information flow and security and privacy. Exposure to cutting-edge research topics in information theory and its applications. Ability to extract information from scientific papers in the field, and acquisition of technical writing and presentation skills.

Syllabus:

Part I: Principles

1. Information Measures: entropy; relative entropy; mutual information; Jensen's inequality; Fano's inequality; data processing in- equality.

2. Source Coding: asymptotic equipartition; source coding theorem – achievability and converse; source codes – Huffman coding, Shannon-Fano-Elias coding, arithmetic coding, Lempel-Ziv coding.

3. Channel Coding: joint asymptotic equipartition property; channel coding theorem – achievability and converse; channel codes.

4. Rate Distortion Theory: rate distortion function; rate distortion theorem – achievability and converse; channel capacity and rate dis- tortion function computation algorithms.

5. Multiuser Information Theory: multiple-access channel; broad- cast channel; relay channel; Slepian-Wolf coding; source coding with side information; rate distortion with side information.

Part II: Applications

1. Wireless Systems and Networks.

2. Sensor Networks.

3. Network Information Flow.

4. Security and Privacy.

Teaching methodologies (including evaluation):

The course is composed by a series of lectures, discussions, and student assignments and presentations. In accordance with the philosophy of the course, the theoretical material will be complemented with specific application examples and case-studies. The student assessment is based on the following key components:

- 50% Final Exam
- 40% Assignments and Presentations
- 10% Class Participation

Main References

- *T. M. Cover and J. A. Thomas. Elements of Information Theory, 2nd Edition. John Wiley & Sons, New York, 2006.*
- *R. G. Gallager. Information Theory and Reliable Communication. John Wiley & Sons, New York, 1968.*
- *R. W. Yeung. A First Course in Information Theory. Springer, New York, 2002.*
- *D. J. C. MacKay. Information Theory, Inference and Learning Algorithms. Cambridge University Press, Cambridge, 2003.*

MANDATORY COURSES

Tópicos Especiais / Special Topics

Professor: Aurélio Joaquim de Castro Campilho

Learning outcomes of the curricular unit:

Special Topics is an elective course offered in both semesters but the students may only do it once. The course assumes two different forms:

1. As a planned individual study on a topic not covered in the programme, but considered relevant for the topic of the thesis. In this case, the requirements are defined by the professor supervising the study.

2. As a teaching assignment, involving the students in teaching activities, in DEEC/FEUP. The goals are the following:

- To give PDEEC students the opportunity to be involved in teaching activities in Master Degree Courses offered in the Department of Electrical and Computer Engineering;
- To create opportunities for the students to use their expertise and skill to co-operate in the development of course curriculum;
- To give the students the opportunity to co-operate in course planning;
- To expose the students to teaching activities at lab level to a limited number of students and at a lecture hall to the entire class.

Syllabus:

The requirements in the first form (individual study) are defined by the professor supervising the study.

The requirements in the second form (teaching assignment), are:

• *Preparation of lab work: set-up the experiments, prepare the theoretical background and elaborate the experimental guide (at least 4 lab works);*

• *Teaching activity in lab classes: to assist lab classes, accompanying students and evaluation activities of lab work;*

• *Teaching activity in theoretical classes: to teach two different topics in theoretical classes.*

Teaching methodologies (including evaluation):

Depending on the form selected by the student: Individual Study ou Teaching Activity.

Distributed evaluation without final exam.

Main References

It depends on the activity used for the curriculr unit

Seminários / Seminars

Professor: Aurélio Joaquim de Castro Campilho

Learning outcomes of the curricular unit:

This course aims at providing Students with multidisciplinary background knowledge that is relevant to their activity as PhD Students and Researchers. Seminars will introduce Students to scientific research methodologies, as detailed in the Program below.

Syllabus:

Seminars is organized in modules of short duration, introducing Students to scientific research methodologies. These modules will cover: 1) How to write a scientific document; 2) How to use U. Porto Library resources; 3) Research Methods; Other topics, within the scope of this course, will be handled in Seminars by Invited Speakers, and will explore themes relate to the main areas in which Students can frame their theses. A final series of Seminars will be handled by PhD Students in their final studies, promoting the integration of the new students and raising the awareness to the research already being conducted in the Faculty and in the research institutes.

Teaching methodologies (including evaluation):

The course will be organized in one weekly Seminar. During the Seminar the course topics previously introduced will be presented.

Distributed evaluation without final exam.

The components for student evaluation are:

- A – Attendance to Seminars
- P – Project (Written Report and Oral Presentation) on a Seminar by an Invited Speaker or a Ph.D. Std

Each component will receive a grading in 0-20

The final score will be calculated according to the following rule:

30% * A + 70% * P

Grading will be from 0 to 20. A passing grade corresponds to a minimum of 10.

Main References

This course consists of a series of seminars focusing on various areas, with speakers ranging from year to year, so it has no specific bibliography recommended.

Plano de Tese / Research Plan

Professor: Aníbal Castilho Coimbra de Matos

Learning outcomes of the curricular unit:

During Individual Topics, students should define the scope and topic of the PhD research. Typically, this consists in identifying the state-of-the-art material, and developing a draft research plan. The work carried out within the scope of this course should contribute for the Thesis Research Plan (TRP) to be submitted for oral exam up to the end of first semester of the second year in PDEEC.

Syllabus:

The student must write a report (about 15 to 20 pages) with a state-of-the-art survey on the topic of the PhD thesis, identifying the subject of the thesis, together with some preliminary results, if they exist, and a draft of the work plan.

Teaching methodologies (including evaluation):

The work in this course will be developed together with a supervisor, who needs to be defined as soon as possible. Although advantageous, the supervisor for this course doesn't need to be the PhD supervisor, who will be appointed by the Scientific Committee of PDEEC afterwards.

Each student and his supervisor for this course have to submit to the course coordinator an abstract (one page max) describing the topic that will be addressed.

Distributed evaluation without final exam

The final grade (FG) of the course will be computed as

$$FG=0.55xSV + 0.25xEE + 0.2xCT$$

where SV, EE, and CT are the grades given by the supervisor (work+report), the external expert (report), and the course coordinator (report+presentations), respectively. Both the supervisor and the external expert are expected to write a short individual report justifying the given grades.

Main References

- *E. Philips, D. Pugh (2005): How to get a PhD: A Handbook for Students and their Supervisors, (Open University Press, Milton Keynes).*

Tese / Thesis

Professors: Assigned supervisors

Learning outcomes of the curricular unit:

PDEEC students prepare their PhD Theses under the supervision of one supervisor and eventually a co-supervisor.

Until the end of the second year students are expected to submit a thesis proposal to a supervising committee as a requirement for proceeding with the thesis work.

In the end, they submit a PhD Thesis in a scientific topic where they have to show original contributions, expertize and knowledge about the state of the art. It is expected when they submit the PhD theses have for publication of at least one paper in a international journal.

Syllabus:

PDEEC Students develop their PhD Theses under a supervision of a Supervisor and eventually a co-supervisor. The topic of the thesis is approved by the PDEEC Scientific Committee and the research plan is approved by a Supervising Committee in a public defense.

Teaching methodologies (including evaluation):

The thesis is defended in a public session with a board of examiners comprising the dean, that presides, or by whom it receives delegation for this purpose, a minimum of three to a maximum of five members holders of Doctorate degree, experts in the thesis area, and the supervisor and co-supervisor(if any).

Main References

Depending on each student thesis

- *Alexandre Pereira, Carlos Poupa; Como escrever uma tese. ISBN: 972-618-350-2 Rita S. Brause; Writing your doctoral dissertation. ISBN: 0-750-70744-5*