DEI
DIPARTIMENTO DI
INGEGNERIA DELL'INFORMAZIONE

UNIVERSITÀ
DEGLI STUDI
DI PADOVA

Ph.D. School in Information Engineering

Course Catalogue

A.Y. 2018/2019

Rev. 2.4 - 20/11/2018

Revision History

Reference version: 2.2 - 25/10/2018

Rev. 2.4 (20/11/2018)

- Classes time table: explicit indication of class time table deleted and replaced with reference to the online Course Calendar
- Course *SK 2. Python programming for Scientific Engineering:* new schedule, class meets on Thursday, 14:30 - 16:30, and Friday, 10:30 - 12:30. First lecture on Thursday, November 22th, 2018.
- Course *IE 16. Imperfect Information and Reasoning*: course duration and credits increased to 20 hours and 5, respectively.
- Course *IE 20. From Electric Grids to Smart Grids:* title changed to *Power Flow Problem in Transmission and Distribution Networks* and syllabus updated.
- Course *IE 21. Heuristics for Mathematical Optimization:* new schedule, class meets every Tuesday and Wednesday from 12:30 to 14:30. First lecture on February 26th, 2019.
- *Course IE 22. Super-resolution imaging: from physics to data*: schedule and room added.

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Summary

General Information

Courses - Soft Skills Area

Courses - Information Engineering Area

Coursework Requirements

The following requirements are valid for Ph.D. Students entering in October 2018 (34° cycle).

General requirements:

- take Ph.D. courses for **a minimum of 20 credits** by the end of the second year;
- **at least 10** of the above 20 credits shall be earned by the end of the first year;
- attend at least three seminars of the **Ph.D. School Seminar Series** by the end of the second year;
- attend at least two modules of the **PhD Educational Week on Transferable Skills 2019**;
- attend all the lectures of the **Distinguished Lecturer Series program** offered during the three-year Ph.D. course.

Specific constraints to earn the minimum of 20 credits of courses:

- **Soft Skills Area (SK)**: at least 5 credits should come from courses belonging to the Soft Skills area (labeled **SK** in the course Summary; please note that the seminars of the Ph.D. Seminar Series and the modules of the PhD Educational Week on Transferable Skills belong to the Soft Skill area and, although they do not grant credits, they are subject to the requirements of attendance outlined above).
- **Information Engineering Area (IE)**: at least 10 credits should be earned by taking courses belonging to the Information Engineering Area (IE).
- **External Courses**: up to a maximum of 5 credits may be earned by taking external courses (i.e. courses not organized by our Ph.D. Schools) falling in the following categories:
    - Courses appearing in the list of External Courses approved by the School Council; the list is reported at the end of this Catalogue.
    - Additional external courses might be included into the list after submission of a written request by the student. Requests submitted by November 30th and May 31st will be evaluated by the School Council in December and June, respectively. Students should obtain their Supervisor approval before submitting a request. Only courses including a final exam with grading will be considered.
    - Courses from other Ph.D. School catalogues (provided they include a final exam with grading).

Each first-year student must fill a tentative program of study form and submit it to the Ph.D. School Secretariat within December 31st. The program of study may be subsequently modified by submitting a new form no later than June 30th of the second year.

Students are expected to attend classes regularly. Punctuality is expected both from instructors and students. Instructors have to report to the Coordinator of the Ph.D. School students missing classes without proper excuse.

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Class Schedule

The class schedule is embedded in the Ph.D. School Calendar. If you have a Google account, you may visualize the class schedule through the following link:

Class Schedule of 2018/19 PhD Courses for Google Calendar

You may also visualize the class schedule using any browser through the following link:

Class Schedule of 2018/19 PhD Courses

Most classes meet in DEI/D meeting room, located at the 1st floor of DEI/D building, location (4) in the map below, or in Room 318 DEI/G, located at the 3rd floor of DEI/G Building, location (3) in the map below, at the Dept. of Information Engineering, via Gradenigo 6/A, Padova.

Please, always check the class schedule in the calendar to verify the class meeting room.

In order to locate the rooms, you may find helpful the map of the Department buildings:

Map of the Department of Information Engineering

SK 1. Technology entrepreneurship and lean start up

Course Area: Soft Skills

Credits: 5

Teacher: Adriano La Vopa

e-mail: adriano@smartangle.it

Aim: The course aims to develop a set of entrepreneurial skills in order to bring a simple idea from the "aha moment" till a business model. Students will learn how to create a solid model of their business around an idea with such a potential. They will learn how to use some tools for creating their own business, how to get feedback from the market and how to pitch it to possible investors. Students will apply a "learn by doing" approach and will work on practical cases driven by their own motivation.

Background material: No background material is necessary. The course will be held in English.

Modules:

- **Module 1: Business, what's this?** [4 h module – 2 sessions]

In this module students will learn: how a company is governed: managers, board members, shareholders and stakeholders; some examples of businesses: start up, scale up, spin up, spin off, spin out; customer centricity versus product development; phases of company life.

- **Module 2: Building a business?** [4 h module – 2 sessions]

In this module students will learn: creating a business by means of strategic tools: Business Model Canvas and all its parts; concept of Minimum Viable Product (MVP); business metrics; Intellectual Property (IP), protection and importance.

- **Module 3: Getting the money** [4 h module – 2 sessions]

In this module students will learn: funding opportunities like crowdfunding; the equity funding; business angels and venture capital.

- **Module 4: Role game** [8 h module – 2 sessions]
    - Creating a venture from students' ideas: this module will consist of 6 hours that will be aiming to working on a business model, meeting the customers and creating an MVP concept to be launched on the market.
    - Dragons' Den session: real case pitching of 2 hours in front of a panel that will decide or not to invest in your company.

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References: all material will be available in PDF format on the course web site.

Timing: Course of 20 hours.

Schedule: please, see Class Schedule

Room: DEI/D meeting room, Dept. of Information Engineering, DEI/D Building, 1st floor (map).

Course requirements: familiarity with basic math.

Examination and grading: homework and pitch-like exam.

SK 2. Python programming for Scientific Engineering

Course Area: Soft Skills

Credits: 5

Instructor: Dr. Stefano Michieletto

e-mail: michieletto@dei.unipd.it

Aim: "Python is an easy to learn and powerful programming language." Python is becoming more and more popular for scientific applications such as machine learning, integrate and interpolate numerical information, manipulate and transform data. The first objective of the course is to become familiar with Python syntax, environments and basic libraries. The learner will be guided in performing basic inferential data analyses and introduced to the application of common machine learning algorithms.

Topics:

- A Quick Tour of Python Language Syntax
  - Python Basic Uses
  - What is different in Python?
- Modules and Packages
  - NumPy: Numerical Python
  - Pandas: Labeled Column-Oriented Data
  - Matplotlib: MATLAB-style scientific visualization
  - SciPy: Scientific Python

References:

[1] J. VanderPlas, "A Whirlwind Tour of Python", O'Reilly Media Inc. 2016. [Online: https://www.oreilly.com/programming/free/files/a-whirlwind-tour-of-python.pdf]

[2] J. VanderPlas, "Python Data Science Handbook: Essential Tools for Working with Data" O'Reilly Media Inc. 2017.

[3] B. Miles, "Begin to Code with Python", Pearson Education, Inc. 2018. [Online: https://aka.ms/BeginCodePython/downloads]

[4] Z. Shaw, "Learn Python the Hard Way", Addison-Wesley. 2014.

[5] L. Ramalho "Fluent Python", O'Reilly Media Inc. 2015.

Schedule: please, see Class Schedule

Room: DEI/D meeting room, Dept. of Information Engineering, DEI/D Building, 1st floor (map).

Course requirements: Backgrounds in computing with some object-oriented programming language: C++, Java, MATLAB, etc. If you are starting from scratch, please have a look at [3] or [4].

Examination and grading: Homework assignments and final project.

SK 3. Ph.D. School Seminar Series

Course Area: Soft Skills

Credits: 0 (no credits granted; students are required to attend at least three of the seminars listed below by the end of their second year)

Program:

1. Building a Research Career: A Success Story (prof. F. Nestola)
2. International Funding Opportunities for Young Researchers (IRO)
3. Etica pubblica (prof. U. Vincenti)
4. Gestione dei rischi industriali (dr. F. Targa)
5. TBA

SK 3.1. Building a Research Career: A Success Story

Course Area: Soft Skills

Credits: 0 (no credits granted; students are required to attend at least three of the seminars listed in section SK. 3 by the end of their second year)

Instructor: Professor Fabrizio Nestola, Department of Earth Sciences, Università di Padova

e-mail: fabrizio.nestola@unipd.it

Abstract: Fabrizio Nestola, Full Professor in Mineralogy at the University of Padova, ERC Grant recipient, explains how to start planning a successful career as an academic or industrial researcher right from the beginning of the Ph.D.

Time table: TBD.

Room: TBD.

SK 3.2. International Funding Opportunities for Young Researchers

Course Area: Soft Skills

Credits: 0 (no credits granted; students are required to attend at least three of the seminars listed in section SK. 3 by the end of their second year)

Instructor: International Research Office, Università di Padova

e-mail: international.research@unipd.it

Abstract:

Presentation of the International Research Office.

How to build an international career for junior researchers: examples of successful CV's in major international funding programs.

Hunting for information and funding opportunities: Euraxess and Scival Funding research engines.

Marie Skłodowska-Curie (MSCA) program with focus on Individual Fellowships (IF) and Co-Funding of Regional, National and International Programmes (COFUND) actions.

European Research Council (ERC) funding scheme with focus on Starting Grant (StG).

Additional individual funding opportunities to build and support an international career.

Writing an individual proposal for a post-doctoral position.

Time table: TBD.

Room: 318 DEI/G, Dept. of Information Engineering, DEI/G Building, 3rd floor.

SK 3.3. Etica pubblica

Important note: This seminar will be held in Italian language

Course Area: Soft Skills

Credits: 0 (no credits granted; students are required to attend at least three of the seminars listed in section SK. 3 by the end of their second year)

Instructor: Professor Umberto Vincenti, Dipartimento di diritto privato e critica del diritto (DPCD), Università di Padova

e-mail: umberto.vincenti@unipd.it

Aim: Nella convinzione che vi sia oggi urgente bisogno di un'etica che offra ai vari attori criteri idonei a valutare azioni e atti di governo e di amministrazione, senza mutuare parametri o indicazioni provenienti da autorità e poteri non pubblici, scopo dell'iniziativa è quello di esporre e divulgare i grandi principi dell'etica pubblica in una repubblica costituzionale e democratica come è la nostra. E' un'etica pubblica che si deve costruire per congruenza con i caratteri del modello repubblicano di governo alla cui definizione hanno contribuito elaborazioni teoriche e esperienze pratiche lungo duemilacinquecento anni di storia occidentale.

1. In questo contesto si analizzano gli indici di riconoscimento del buon cittadino, del buon governante, del buon amministratore. A particolare indagine è sottoposta l'idea di bene comune in relazione alla necessità di pervenire ad individuarne un significato plausibile nella contemporaneità; e poi di trovarne il modo del suo coordinamento con gli interessi particolari, oggi spesso assunti nel novero dei diritti individuali giuridicamente garantiti.
2. Una particolare attenzione viene riservata all'etica di imprese e professioni che dovranno essere modulate nella prospettiva della responsabilità sociale, superando i limiti, ormai angusti, della correttezza nell'espletamento dell'attività affinché essa risulti gradita alla committenza o,

anche, ai consumatori in genere, generandosi, invece dei doveri, in virtù dell'agere stesso, verso la collettività locale, nazionale, talora globale, non solo presente, ma anche futura.

3. Verranno analizzati, e discussi, alcuni casi concreti di condotte eticamente scorrette, eventualmente contrarie anche alle previsioni legali: la casistica attingerà da vari settori della vita privata, sociale, istituzionale (particolare attenzione sarà dedicata al mondo universitario).
4. Infine si cercherà di esporre la struttura della comunicazione o del discorso eticamente corretto, individuando i moduli fondamentali del dire e dello scrivere ispirati non soltanto al criterio dell'efficacia persuasiva, ma prima ancora al criterio della collaborazione leale, secondo i principi del rispetto dell'interlocutore, della pertinenza dell'informazione fornita e della sua veridicità ecc.

Schedule: please, see Class Schedule

Room: 318 DEI/G, Dept. of Information Engineering, DEI/G Building, 3rd floor.

SK 3.4. Gestione dei rischi industriali

Important note: This seminar will be held in Italian language

Course Area: Soft Skills

Credits: 0 (no credits granted; students are required to attend at least three of the seminars listed in section SK. 3 by the end of their second year)

Instructor: Dr. Fabio Targa, Lincoln Electric

e-mail: fabiotarga@iol.it

Aim: Il ciclo di lezioni qui proposto è pensato per ricercatori di ingegneria con elevata formazione specialistica, che entreranno nel mondo del lavoro e in poco tempo raggiungeranno posizioni apicali e di responsabilità in strutture private o pubbliche.

L'obiettivo è dare loro un set minimo di conoscenze e strumenti per comprendere i principali rischi industriali comuni alla maggior parte delle attività e le possibili metodologie per affrontarli e risolverli. Il tutto all'interno del quadro normativo italiano ed europeo.

Topics:

I Lezione (2 ore) - Introduzione: Impresa, Responsabilità e Rischi industriali

L'impresa. Il contesto in cui opera un'organizzazione. Definizioni: pericolo, rischio, danno. Come si misura un rischio. Le conseguenze indesiderate delle attività.

II Lezione (2 ore) - Le fonti e tipologie dei rischi industriali

Organizzazione. Conformità legislativa delle attività. Cenni di: security, eventi naturali, proprietà intellettuali, protezione dei dati, IT, rischi finanziari.

III Lezione (2 ore) - Come si prevengono i rischi industriali

Politiche e codici etici. Organizzazione aziendale per la prevenzione del rischio. Le deleghe e le nomine. Le procedure aziendali. Modelli di sistema di gestione. Modello organizzativo ex D. Lgs. 231/01.

IV Lezione (2 ore) - Gestione di Ambiente, igiene e Sicurezza EHS

Un po' di storia. Infortuni e malattie professionali. Il D. Lgs. 81/08 ("Testo unico in materia di salute e sicurezza nei luoghi di lavoro"). Il Documento di Valutazione dei Rischi. Il D. Lgs. 152/2006 ("Testo Unico Ambiente"). Classificazione del rischio. Individuazione delle misure. Piano d'azione. Formazione e informazione.

Schedule: please, see Class Schedule

Room: 318 DEI/G, Dept. of Information Engineering, DEI/G Building, 3rd floor (map).

SK 4. PhD Educational Week on Transferable Skills

Course Area: Soft Skills

Credits: 0 (no credits granted; students are required to attend at least two modules offered in the PhD Educational Week on Transferable Skills)

Aim: the PhD Educational Week on Transferable Skills (PhDETSWeek) is a five-day event specifically conceived to help Ph.D. students to increase their soft-skills. Five main areas will be covered (one per day):

Area 1 - Communication/Public Speaking

Area 2 - Professional Development

Area 3 - Entrepreneurship

Area 4 - Personal Development

Area 5 - Funding opportunities and writing skills

Timetable: TBD (sometimes in June 2019).

Program: The final program will be available at the beginning of 2019. In the meantime, you may want to take a look at the program of PhDETSWeek 2018 (use your SSO credentials to authenticate and download the flyer).

DL 1. Distinguished Lecturer Series 2019

Credits: 0 (no credits granted; students are required to attend all the lectures of the DLS offered during their three-year Ph.D. program)

The Distinguished Lecturer Series (DLS), active since 2004, is an annual program of high impact lectures where internationally renowned scholars are invited to discuss cutting-edge research in ICT and neighboring disciplines. While aiming at scientific excellence, our lectures are typically open to the general public as well.

The DLS 2019 program is in preparation. You will find up-to-date information on the program on the Department website at the beginning of 2019:

https://www.dei.unipd.it/ → RICERCA → Distinguished Lecturer Series

IE 1. Bayesian Machine Learning

Course Area: Information Engineering

Credits: 5

Instructor: prof. Giorgio Maria Di Nunzio

e-mail: dinunzio@dei.unipd.it

Aim: The course will introduce fundamental topics in Bayesian reasoning and how they apply to machine learning problems. In this course, we will present pros and cons of Bayesian approaches and we will develop a graphical tool to analyse the assumptions of these approaches in classical machine learning problems such as classification and regression.

Topics:

- Introduction of classical machine learning problems.
    - Mathematical framework
    - Supervised and unsupervised learning
- Bayesian decision theory
    - Two-category classification
    - Minimum-error-rate classification
    - Bayes decision theory
    - Decision surfaces
- Estimation
    - Maximum Likelihood Estimation
    - Expectation Maximization
    - Maximum A Posteriori
    - Bayesian approach
- Graphical models
    - Bayesian networks
    - Two-dimensional visualization
- Evaluation
    - Measures of accuracy

References:

[1] J. Kruschke, Doing Bayesian Data Analysis: A Tutorial Introduction With R and Bugs, Academic Press 2010

[2] Christopher M. Bishop, Pattern Recognition and Machine Learning (Information Science and Statistics), Springer 2007

[3] Richard O. Duda, Peter E. Hart, David G. Stork, Pattern Classification (2nd Edition), Wiley-Interscience, 2000

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[4] Yaser S. Abu-Mostafa, Malik Magdon-Ismail, Hsuan-Tien Lin, Learning from Data, AMLBook, 2012 (supporting material available at http://amlbook.com/support.html)

[5] David J. C. MacKay, Information Theory, Inference and Learning Algorithms, Cambridge University Press, 2003 (freely available and supporting material at http://www.inference.phy.cam.ac.uk/mackay/

[6] David Barber, Bayesian Reasoning and Machine Learning, Cambridge University Press, 2012 (freely available at http://web4.cs.ucl.ac.uk/staff/D.Barber/pmwiki/pmwiki.php?n=

[7] Kevin P. Murphy, Machine Learning: A Probabilistic Perspective, MIT Press, 2012 (supporting material http://www.cs.ubc.ca/ murphyk/MLbook/)

Schedule: please, see Class Schedule

Room:

- Thursday lectures: 318 DEI/G, Dept. of Information Engineering, DEI/G Building, 3rd floor.
- Friday lectures: Te, Dept. of Information Engineering, DEI/G Building, 2nd floor.

Course requirements: Basics of Probability Theory. Basics of R Programming.

Examination and grading: Homework assignments and final project.

IE 2. Advanced Algorithms and Data Structure for Sequence Analysis

Course Area: Information Engineering

Credits: 5

Instructor: prof. Cinzia Pizzi

e-mail: cinzia.pizzi@dei.unipd.it

Aim: The class is intended to give a survey of advanced data structures and algorithms for the analysis of sequences in a variety of application fields, such as text mining, biological sequence analysis, data compression, and time series analysis.

Topics:

1. Suffix based data structures: suffix trees, suffix arrays, and their applications
2. The Burrows-Wheeler transform and compressed indexes
3. Alignment free algorithms for sequence comparison
4. The Symbolic Aggregate approXimation (SAX) for time series analysis

References:

[1] V.Makinen, D.Belazzougui, F.Cunial, A.I.Tomescu: Genome scale algorithm design, Cambridge University Press, 2015

[2] J.Lin, E. Keogh, L.Wei, S.Lonardi: Experiencing SAX: a novel symbolic representation of time series, Data mining and Knowledge Discovery, 2007

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

Schedule: please, see Class Schedule

Room: 318 DEI/G, Dept. of Information Engineering, DEI/G Building, 3rd floor (map).

Course requirements: Fundamentals of data structures and computational complexity

Examination and grading: Final project on the application of the algorithms and data structures presented during the course to a problem on an application field of interest to the student, or in-depth analysis of a problem and oral presentation of specialized algorithms and/or data structure available in literature to solve it.

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IE 3. Fluid mechanics for the functional assessment of cardiovascular devices

Course Area: Information Engineering

Credits: 4

Instructor: Francesca Maria Susin, Dept. ICEA, University of Padua

e-mail: francescamaria.susin@unipd.it

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

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

References:

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

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

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

[4] A.P. Yoganathan, Z. He and S. Casey Jones. Fluid mechanics of heart valves.

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

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

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

[8] M.J. Slepian, Y. Alemu, J.S. Soares. R.G. Smith, S. Einav and D. Bluestein. The Syncardia total arti cial heart: in vivo, in vitro, and computational modeling studies. Journal of Biomechanics,46 (2013): 266-27, 2013.

Schedule: please, see Class Schedule

Room: 318 DEI/G, Dept. of Information Engineering, DEI/G Building, 3rd floor (map).
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Course requirements: Fundamentals of Fluid Dynamics.

Examination and grading: Homework assignment with final discussion.

IE 4. Applied Functional Analysis and Machine Learning

Course Area: Information Engineering

Credits: 7

Instructor: prof. Gianluigi Pillonetto

e-mail: giapi@dei.unipd.it

Aim: The course is intended to give a survey of the basic aspects of functional analysis, machine learning, regularization theory and inverse problems.

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

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

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

Reproducing kernel Hilbert spaces, inverse problems and regularization theory: Representer theorem. Reproducing Kernel Hilbert Spaces (RKHS): definition and basic properties. Examples of RKHS. Function estimation problems in RKHS. Tikhonov regularization. Primal and dual formulation of loss functions. Regularization networks. Consistency/generalization and relationship with Vapnik's theory and the concept of V-gamma dimension. Support vector regression and classification.

References:

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

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

Schedule: please, see Class Schedule

Room: 318 DEI/G, Dept. of Information Engineering, DEI/G Building, 3rd floor **with the exception of Jan. 9th, 2019**, DEI/D meeting room, Dept. of Information Engineering, DEI/D Building, 1st floor (map).

Course requirements: The classical theory of functions of real variable: limits and continuity, differentiation and Riemann integration, infinite series and uniform convergence. The arithmetic of complex numbers and the basic properties of the complex exponential function. Some elementary set theory. A bit of linear algebra.

Examination and grading: Homework assignments and final test.

IE 5. Brain-Computer Interface for Neurorobotics

Course Area: Information Engineering

Credits: 5

Instructor: Dr. Luca Tonin

e-mail: luca.tonin@epfl.ch

Aim: The course aims to introduce doctoral students to the Brain-Computer Interface (BCI) field, in particular applied to Neurorobotics. The course will provide advanced tools and methodologies for analyzing and decoding brain signals and for translating them into actions of external actuators. Multidisciplinary topics will be presented in order to cover the different parts that compose standard BCI systems: methods for processing neurophysiological signals, tools for machine learning and decision making, topics for control strategies of robotic devices. Each topic will be faced from the theoretical and practical point of view, by means of frontal lectures and exercises to be solved both during classes and as homeworks (in Matlab). The final project will focus on the implementation of a simulated-online BCI system.

Topics:

- Introduction of current BCI systems based on Electroencephalography (EEG). General concepts of BCI: structure, modules and applications for control and rehabilitation. BCI based on evoked potentials. BCI based on sensorymotor rhythms. BCI based on voluntary attention focus.
- Application of signal processing techniques to analyze EEG signals. Stationarity and non-stationarity of brain signals. EEG bands. Spatial and spectral filters.
- Application of Machine Learning algorithms to classify EEG signals Machine learning approaches to BCI. Classical classifiers exploited in BCI field (e.g., LDA, QDA, Gaussian). Concepts of calibration and testing sessions. Stability of the classifier over sessions.
- Application of probabilistic frameworks to decode intention to move Decision making algorithms. Applications of bayesian probabilistic framework to decode sen- sorymotor rhythms.
- High-level BCI control of robotic actuators From the BCI output to the device control. Dealing with a noisy control signal. Common approaches to drive complex robotic devices.
- Implementation of an online BCI system from the beginning A real BCI experiment: subject setup, recording, calibration and testing. Experiment will be performed during the class. Critical points in the implementation of a working BCI loop. The recorded data will be used by students for the final project. References: [1] D. J. McFarland and J. R. Wolpaw, Brain-Computer interface operation of robotic and pros- thetic devices, Computer (Long. Beach. Calif)., vol. 41, no. 10, pp. 5256, 2008.

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References:

[1] D. J. McFarland and J. R. Wolpaw, Brain-Computer interface operation of robotic and prosthetic devices, Computer (Long. Beach. Calif)., vol. 41, no. 10, pp. 5256, 2008.

[2] J. R. Wolpaw, Brain-computer interfaces for communication and control, Clin. Neurophysiol., vol. 113, no. 6, pp. 76791, 2002.

[3] N. Birbaumer, Breaking the silence: Brain-computer interfaces (BCI) for communication and motor control., Psychophysiology, vol. 43, no. 6, pp. 51732, 2006.

[4] J. d. R. Millan, et al., Combining brain-computer interfaces and assistive technologies: State-of-the-art and challenges., Front. Neurosci., vol. 4, no. September, pp. 115, 2010.

[5] G. R. Muller-Putz, et al., Tools for Brain-computer interaction: A general concept for a hybrid BCI., Front. Neuroinform., vol. 5, no. November, p. 30, 2011.

[6] R. Leeb, et al., Towards Independence: A BCI Telepresence Robot for People With Severe Motor Disabilities, Proc. IEEE, vol. 103, no. 6, p. 969-982, 2015.

[7] S. Perdikis, et al., The Cybathlon BCI race: Successful longitudinal mutual learning with two tetraplegic users, PLOS Biol., vol. 16, no. 5, e2003787, 2018.

[8] C. M. Michel, et al., eds. Electrical Neuroimaging. 1st ed. Cambridge: Cambridge University Press, 2009.

[9] C. M. Bishop, Neural Networks for Pattern Recognition. Oxford University Press, Inc., New York, NY, USA, 1995.

Additional selected reference material will be handed out during the course.

Schedule: please, see Class Schedule

Room: 318 DEI/G, Dept. of Information Engineering, DEI/G Building, 3rd floor (map).

Course requirements: Basic knowledge of Signal Processing. Basic knowledge of Machine Learning. Knowledge of Matlab.

Examination and grading: Homework assignments and final project.

IE 6. Social Robotics

Course Area: Information Engineering

Credits: 4

Instructor: Dr. Salvatore M. Anzalone. CHArt Lab, Université Paris 8, Saint-Denis, France.

e-mail: sanzalone@univ-paris8.fr

Aim: The goal of the course is to give the basic knowledge for analysing, modeling, and developing robotics systems able to interact with humans in a natural way. At the end of the module the students will have acquired theoretical, procedural and practical concepts of social robotics. In particular, by employing the acquired knowledge in robotics, the students will be able to develop interactive systems using the humanoid robot Nao, through the use of the software ”Choreographe proposed by Softbank Robotics.

Topics:

1. Introduction to robotics
2. Autonomous robots
3. Social robotics
4. Verbal and non-verbal communication
5. Design and evaluation of interactive systems
6. Ethics

References:

[1] Brooks, Rodney A. Elephants don’t play chess. Robotics and autonomous systems 6.1-2 (1990): 3-15.

[2] Brooks, Rodney A. Intelligence without reason. Artificial intelligence: critical concepts 3 (1991): 107-63.

[3] Kajita, Shuuji, et al. Biped walking pattern generation by using preview control of zero-moment point. Robotics and Automation, 2003. Proceedings. ICRA’03. IEEE International Conference on. Vol. 2. IEEE, 2003.

[4] Breazeal, Cynthia L. Designing sociable robots. MIT press, 2004.

[5] Vinciarelli, Alessandro, Maja Pantic, and Herv Bourlard. Social signal processing: Survey of an emerging domain. Image and vision computing, 2009.

[6] Vinciarelli, Alessandro, et al. Bridging the gap between social animal and unsocial machine: A survey of social signal processing. IEEE Transactions on Affective Computing, 2012.

[7] Siciliano, Bruno, and Oussama Khatib, eds. Springer handbook of robotics. Springer Science & Business Media, 2008.

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[8] Metta, Giorgio, et al. The iCub humanoid robot: an open platform for research in embodied cognition. Proceedings of the 8th workshop on performance metrics for intelligent systems. ACM, 2008.

[9] Pot, Emmanuel, et al. Choregraphe: a graphical tool for humanoid robot programming. Robot and Human Interactive Communication, 2009. RO-MAN 2009. The 18th IEEE International Symposium on. IEEE, 2009.

[10] Delaherche, Emilie, et al. Interpersonal synchrony: A survey of evaluation methods across disciplines. IEEE Transactions on Affective Computing 3.3 (2012): 349-365.

[11] Anzalone, Salvatore M., et al. Evaluating the engagement with social robots. International Journal of Social Robotics 7.4 (2015): 465-478.

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

Schedule: please, see Class Schedule

Room: DEI/D meeting room, Dept. of Information Engineering, DEI/D Building, 1st floor (map).

Course requirements: Basic Python scripting. No other background material is necessary.

Examination and grading: The students will be evaluated using written tests, through multiple choices questionnaires, essay questions and a mini project. An evaluation grid will be given to the students at the same time with the tests.

IE 7. Real-Time Systems and applications

Course Area: Information Engineering

Credits: 5

Instructor: Dr. Gabriele Manduchi, Consiglio Nazionale delle Ricerche

e-mail: gabriele.manduchi@igi.cnr.it

Aim: The course will provide an insight in the realm of real-time system. Knowledge in this field is normally fragmented and scattered among different engineering disciplines and computing sciences, and the aim of the course is present aspects related to theory and practice in a way which is holistic enough to prepare graduates to embark on the development of real-time systems, frequently complex and imposing safety requirements

Topics:

- . Introduction via a case study: a system tracking circular objects;
- Operating Systems review;
- Tasks, threads and interprocess communication;
- Real-time scheduling: definitions, cyclic executive, utilization based scheduling, response time analysis, priority inheritance;
- Data Acquisition techniques;
- GPU and FPGA architectures in real-time applications

References:

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

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

Schedule: please, see Class Schedule

Room: DEI/D meeting room, Dept. of Information Engineering, DEI/D Building, 1st floor (map).

Course requirements: Basic knowledge of Operating System concepts.

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

IE 8. Computational Inverse Problems

Course Area: Information Engineering

Credits: 5

Instructor: Fabio Marcuzzi, Dept. of Mathematics, University of Padova.

e-mail: marcuzzi@math.unipd.it

Aim: We study numerical methods that are of fundamental importance in computational inverse problems. Real application examples will be given for distributed parameter systems in continuum mechanics. Computer implementation performance issues will be considered as well.

Topics:

- definition of inverse problems, basic examples and numerical difficulties.
- numerical methods for QR and SVD and their application to the square-root implementation in PCA, least-squares, model reduction and Kalman filtering; recursive least-squares;
- regularization methods;
- numerical algorithms for nonlinear parameter estimation: Gauss-Newton, Levenberg-Marquardt,
- examples with distributed parameter systems in continuum mechanics; HPC implementations

References:

[1]F.Marcuzzi "Analisi dei dati mediante modelli matematici", http://www.math.unipd.it/~marcuzzi/MNAD.html

Schedule: please, see Class Schedule

Room: 318 DEI/G, Dept. of Information Engineering, DEI/G Building, 3rd floor (map).

Course requirements:

- basic notions of linear algebra and, possibly, numerical linear algebra.
- the examples and homework will be in Python (the transition from Matlab to Python is effortless).

Examination and grading: Homework assignments and final test.

IE 9. Diagnostics of Electron Devices

Course Area: Information Engineering

Credits: 4

Instructor: Proff. Giovanna Mura, Massimo Vanzi - Department of Electrical and Electronic Engineering (DIEE), University of Cagliari.

e-mail: gmura@diee.unica.it, vanzi@diee.unica.it

Aim: this course provides an overview of the Failure Analysis techniques for the diagnostics of electron devices. Failure analysis is the process of analyzing the failed electron devices to determine the reason for degraded performance or catastrophic failure and to provide corrective actions able to x the problem. It is a proactive tool with three fundamental tasks: 1) Technical/scientific: 2) Technological 3) Economical. The purpose of this course is to teach what Failure Analysis should be and should do, to show how and why it often does not, to state that F.A. has Logics and has Rules.

Microscopy, in its several forms (optical, electron, scanning, transmission, emission, ionic) and tools is the playground for practical FA, and its fundamentals will be described. Device basic technology, working principle and failure physics are the other pillars for a successful study.

Several case studies will be proposed with the aim to demonstrate that if sometimes Failure Analysis looks unclear or not problem solving is merely because it was badly conducted.

Topics:

1. Reverse engineering
2. Failure modes and failure mechanisms
3. Principles and fundamental methods in Electron Microscopy
4. Methodology for the Failure Analysis

References: Failure Analysis of Integrated Circuits - Tools and Techniques, Springer International Series - Lawrence C. Wagner.

Slides

Schedule: please, see Class Schedule

Room: DEI/D meeting room, Dept. of Information Engineering, DEI/D Building, 1st floor (map).

Course requirements: Electron Devices, Microelectronics, Optoelectronics devices.

Examination and grading: Written test/ presentation of a report at the end of the course

IE 10. Applied Linear Algebra

IMPORTANT NOTE: the inclusion of this course in the Catalogue is still under discussion. Confirmation will be given as soon as possible.

Course Area: Information Engineering

Credits: 4

Instructors: Prof. Fernando De Terán, Universidad Carlos III de Madrid, Prof. Michael Karow, Technische Universität Berlin.

e-mail: fteran@math.uc3m.es, karow@math.tu-berlin.de

Aim: We study concepts and techniques of linear algebra that are important for applications with special emphasis on the topics: (a) solution of systems of linear equations (with particular attention to the analysis of the backward error and computational cost of the basic algorithms) and (b) matrix equations and inequalities. A wide range of exercises and problems will be an essential part of the course and constitute homework required to the student.

Topics:

1. Review of some basic concepts of linear algebra and matrix theory.
2. Gaussian elimination.
3. LU factorization.
4. Positive (semi) de nite matrices and Cholesky factorization.
5. Matrix exponential.
6. Sylvester and Lyapunov equations, Riccati equation.
7. Applications to Control Theory.

References:

[1] Gilbert Strang's linear algebra lectures, from M.I.T. on You Tube

[2] Nicholas J. Higham. Accuracy and Stability of Numerical Algorithms. SIAM, Philadelphia, 2002.

[3] Notes from the instructors

Time table: see IMPORTANT NOTE above.

Room: 318 DEI/G, Dept. of Information Engineering, DEI/G Building, 3rd floor.

Course requirements: A good working knowledge of basic notions of linear algebra as for example in [1]. Some proficiency in MATLAB.

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

IE 11. Statistical Methods

Course Area: Information Engineering

Credits: 6

Instructor: dr. Lorenzo Finesso

e-mail: lorenzo.finesso@unipd.it

Aim: The course will present a small selection of statistical techniques which are widespread in applications. The unifying power of the information theoretic point of view will be stressed.

Topics:

- *Background material.* The noiseless source coding theorem will be quickly reviewed in order to introduce the basic notions of entropy and I-divergence. (a.k.a. relative entropy, Kullback-Leibler distance) between two probability measures.

- *Divergence minimization problems.* Three I-divergence minimization problems will be posed and, via examples, they will be connected with basic methods of statistical inference: ML (maximum likelihood), ME (maximum entropy), and EM (expectation-maximization).

- *Multivariate analysis methods.* The three standard multivariate methods, PCA (principal component analysis), Factor Analysis, and CCA (canonical correlations analysis) will be reviewed and their connection with divergence minimization discussed. Applications of PCA to least squares (PCR principal component regression, PLS Partial least squares). Approximate matrix factorization and PCA, with a brief detour on the approximate Nonnegative Matrix Factorization (NMF) problem. The necessary linear algebra will be reviewed.

- *EM methods.* The Expectation-Maximization method will be introduced as an algorithm for the computation of the Maximum Likelihood (ML) estimator with partial observations (incomplete data) and interpreted as an alternating divergence minimization algorithm à la Csiszár Tusnády.

- *Applications to stochastic processes.* Introduction to HMM (Hidden Markov Models). Maximum likelihood estimation for HMM via the EM method. If time allows: derivation of the Burg spectral estimation method as solution of a Maximum Entropy problem.

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References:

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

Schedule: please, see Class Schedule

Room: DEI/D meeting room, Dept. of Information Engineering, DEI/D Building, 1st floor (map).

Course requirements: familiarity with basic linear algebra and probability.

Examination and grading: Homework assignments

IE 12. Physics and operation of heterostructure-based electronic and optoelectronic devices

Course Area: Information Engineering

Credits: 5

Instructors: Prof Enrico Zanoni, Prof. Gaudenzio Meneghesso, Dr. Matteo Meneghini, DEI, University of Padova.

e-mail: zanoni@dei.unipd.it, gauss@dei.unipd.it, menego@dei.unipd.it

Aim: This course provides an introduction to the physics and operating principles of advanced electronic and optoelectronic devices based on compound semiconductors. These devices are particularly important for several applications: high electron mobility transistors (HEMTs) represent excellent devices for the realization of high frequency communication systems, radars, satellite applications, and high efficiency power converters. On the other hand, LEDs and lasers are high-efficiency monochromatic light sources, that can be used both for lighting applications (with a considerable energy saving), in the biomedical field, and in in photochemistry. Special focus will be given to Gallium Nitride (GaN) based devices, that represent the most promising devices for future power electronics applications. This course will focus on the main aspects related to the physics of heterostructures, on the recombination processes in semiconductors, on carrier transport in heterostructures, on the structure and operating principles of MESFET, HEMTs, GITs, on the trapping and reliability in compound semiconductor devices, on the operating principles of LEDs and lasers, and on parasitics and reliability in LEDs and lasers. An overview of real applications highlighting the capabilities of these devices will also be given.

Topics:

- physics of heterostructures, band diagrams, carrier transport in heterostructures;
- recombination processes in semiconductors; properties of compound semiconductors;
- basic structure of heterojunction transistors, MESFET, HEMT, GIT; parasitics and reliability in HEMTs, LEDs and lasers;
- operating principles of LEDs and lasers;
- methods for advanced characterization of heterojunction based devices; applications of GaN based HEMTs, LEDs and lasers;
- modeling of semiconductor-based devices

References:

Umesh Mishra, Jasprit Singh, Semiconductor Device Physics and Design, Springer, 2008

Ruediguer Quay, Gallium Nitride Electronics, Springer 2008.

Tae-Yeon Seong, Jung Han, Hiroshi Amano, Hadis Morko, III-Nitride Based Light Emitting Diodes and Applications, Springer 2013

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Schedule: please, see Class Schedule

Room: DEI/D meeting room, Dept. of Information Engineering, DEI/D Building, 1st floor (map).

Course requirements: Introductory course of device physics: Microelectronics, Optoelectronic and Photovoltaic Devices.

Examination and grading: Written test at the end of the course.

IE 13. Analysis and Control of Multi-Agent Systems

Course Area: Information Engineering

Credits: 20 hours

Instructor: Prof. Daniel Zelazo, Faculty of Aerospace Engineering Technion Israel Institute of Technology

e-mail: dzelazo@technion.ac.il

Aim: Multi-agent systems, or networked dynamic systems (NDS), are systems composed of dynamic agents that interact with each other over an information exchange network. These systems can be used to perform team objectives with applications ranging from formation flying to distributed computation. Challenges associated with these systems are their analysis and synthesis, arising due to their decoupled, distributed, large-scale nature, and due to limited inter-agent sensing and communication capabilities. This course provides an introduction to these systems via tools from graph theory, dynamic systems and control theory. The course will cover a variety of modeling techniques for different types of networked systems and proceed to show how their properties, such as stability and performance, can be analyzed. The course will also explore techniques for designing these systems. The course will also cover real-world applications by presenting recent results obtained in the distributed formation control and localization of multi-robot systems.

Topics:

- **Lecture 1:** Introduction to NDS; fundamentals of graph theory; algebraic graph theory
- **Lectures 2–3:** Consensus protocol - undirected, directed, switching, non-linear
- **Lectures 4–5:** Formation control - rigidity theory, distance constrained formations
- **Lectures 6–7–8:** Formation control/Localization - bearing rigidity theory, bearing-only formations, network localization
- **Lectures 9–10:** Advanced topics - survey of important results, applications, and open problems

References:

1. M. Mesbahi and M. Egerstedt, Graph Theoretic Methods in Multiagent Networks, Princeton Univer- sity Press, 2010.
2. F. Bullo, Lectures on Network Systems, http://motion.me.ucsb.edu/book-lns, 2017.
3. C. Godsil and G. Royle, Algebraic Graph Theory, Springer, 2009.
4. R. A. Horn and C. R. Johnson, Matrix Analysis, Cambridge University Press, 1990.
5. W. Ren and R. Beard, Distributed Consensus in Multi-Vehicle Cooperative Control, Springer, 2008.
6. S. Zhao and D. Zelazo, Bearing Rigidity and Almost Global Bearing-Only Formation Stabilization, IEEE Transactions on Automatic Control 61(5):1255-1268, 2016.

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7. S. Zhao and D. Zelazo, Localizability and distributed protocols for bearing-based network localization in arbitrary dimensions, Automatica, 69(1):334-341, 2016.

Schedule: please, see Class Schedule

Room: DEI/D meeting room, Dept. of Information Engineering, DEI/D Building, 1st floor (map).

Course requirements: TBA

Examination and grading: TBA

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IE 14. 5G, Enablers and Cloudification

Course Area: Information Engineering

Credits: 5

Instructor: Dr. Emilio Calvanese Strinati, Scientific and Innovation Director, CEA-LETI, France

e-mail: emilio.calvanese-strinati@cea.fr

Aim: The course is an introduction to 5G wireless networks and on its technology enablers. Lectures are planned in the classroom.

In the last years, information communication, computation and storage technologies are jointly reshaping the way we use technology, meeting the future needs of a wide range of big data and artificial intelligence applications and, paving the way for a full customized autonomous user experience. In 2020 the 5G -Next Generation Communication Networks is expected to be operational and a global game changer from a technological, economic, societal and environmental perspective. 5G industry is intensively working today on designing, prototyping and testing fundamental technological advances to de-liver the promised performance in terms of latency, energy efficiency, wireless broadband capacity, elasticity, etc. Nevertheless, many experts says that the next big step for cellular networks is not 5G, it is the cloud. This lecture will cover both architecture and detail technical tools for understanding the key enabling technologies that will enable 5G networks to meet its challenging performance targets and how 'the cloud' will play an operational role in future wireless networks.

Topics:

1. Introduction to evolution of Wireless Networks from 3G+ to 5G. De-tails on technologies enabling the revolution between 4G and future 5G networks.
2. Network densification, resource management and heterogeneous networks
3. Advanced interference management techniques from heuristics to information theory
4. Millimeter waves, Massive MIMO and antenna design Energy efficiency and its advanced techniques
5. The 'cloudification' of 5G: from central-RAN to mobile edge cloud. Details examples of convex optimization tools and millimeter wave spectrum use
6. Energy efficiency and its advanced techniques
7. The overall perspective of 5G, what is expected to be beyond 5G and conclusions.

References:

[1] Emilio Calvanese Strinati, chapter editor Green Femtos/Energy Efficiency Issues of 4G and Beyond Femto Networks: On the road to Small Cells and Smart Heterogeneous Networks, Wiley, 2013.

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[2] A De Domenico, E Calvanese Strinati, M-Di Benedetto, A survey on MAC strategies for cognitive radio networks, IEEE Journal on Communications Surveys & Tutorials, 14 (1), 21-44, 2012.

[3] A De Domenico, E Calvanese Strinati, A Capone, Enabling Green cellular networks: A survey and outlook, Computer Communications 37, 5-24, 2014

[4] K. Sakaguchi, G. K. Tran, H. Shimodaira, S. Namba, T. Sakurai, I. Siaud, K. Takinami, E. Calvanese Strinati, A. Capone, I. Karls, R. Are , T. Haustein, Millimeter-wave Evolution for 5G Networks, IEICE Trans. Communications, 2015.

[5] K. Sakaguchi, T. Haustein, S. Barbarossa, E. Calvanese Strinati, R. W Heath Jr, et al., Where, When, and How mmWave is Used in 5G and Beyond, IEICE Transactions on Communications, 2017.

[6] Ad hoc material by Lecturer.

Schedule: please, see Class Schedule

Room: DEI/D meeting room, Dept. of Information Engineering, DEI/D Building, 1st floor (map).

Examination and grading: Attendance is required for at least 2/3 of the lecture hours. Final evaluation will be based on the discussion of a case study within the individual PhD project.

IE 15. Distributed Optimization and Applications

Course Area: Information Engineering

Credits: 5

Instructor: Prof. Subhrakanti Dey, Signals and Systems, Uppsala University, Sweden.

e-mail: Subhra.Dey@signal.uu.se

Aim: The aim of this course is to introduce postgraduate students to the topical area of Distributed Optimization. As we enter the era of Big Data, engineers and computer scientists face the unenviable task of dealing with massive amounts of data to analyse and run their algorithms on. Often such data reside in many di↵erent computing nodes which communicate over a network, and the availability and processing of the entire data set at one central place is simply infeasible. One needs to thus implemented distributed optimization techniques with message passing amongst the computing nodes. The objective remains to achieve a solution that can be as close as possible to the solution to the centralized optimization problem. In this course, we will start with some history on the origins of distributed optimization algorithms such as the Alternating Direction Method of Multipliers (ADMM), discuss its properties, and applications to both convex and non-convex problems, and explore alternative techniques such as game theoretic methods as well as distributed stochastic optimization methods, and finish with discussions on very recent and largely open areas such as networked optimization and dis- tributed machine learning algorithms. This course will provide a glimpse into this fascinating subject, and will be of relevance to graduate students in Elec- trical, Mechanical and Computer Engineering, Computer Science students, as well as graduate students in Applied Mathematics and Statistics, along with students dealing with large data sets and machine learning applications to Bioinformatics.

Topics:

- Lectures 1 and 2: Precursors to distributed optimization algorithms: parallelization and decomposition of optimization algorithms (dual de- composition, proximal minimization algorithms, augmented Lagrangian and method of multipliers)
- Lecture 3: The Alternating Direction Method of Multipliers (ADMM): (Algorithm, convergence, optimality conditions, stopping criteria, con- strained convex optimization)
- Lecture 4: Applications of ADMM to machine learning problems: l1 norm problems
- Lecture 5: ADMM based methods for solving consensus and sharing problems, ADMM for non-convex problems and examples
- Lecture 6: ADMM Implementation issues and numerical examples

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- Lecture 7: Distributed optimization using non-cooperative game theory (basic theory of Nash equilibrium, existence, uniqueness and eciency)
- Lecture 8: Distributed stochastic optimization and Stochastic Approxi- mation algorithms
- Lecture 9: Networked Optimization (e.g. over a graph) and distributed optimization under communication constraints
- Lecture 10: Applications of distributed optimization to distributed ma- chine learning: a survey for recent results

References:

[1] S. Boyd, N. Parikh, E. Chu, B. Peleato, and J. Eckstein, Distributed Optimization and Statistical Learning via the Alternating Direction Method of Multipliers, Foundations and Trends in Machine Learning, 3(1):1122, 2011.

[2] Dimitri Bertsekas and John N. Tsitsiklis, Parallel and Distributed Computation: Numerical Methods, Athena Scientific, 1997.

[3] S. Boyd and L. Vandenverghe, Convex Optimization, Cambridge University Press.

[4] M. Zhu and S. Martinez, Distributed Optimization-Based Control of Multi-Agent Networks in Complex Environments, Springer, 2015.

Relevant recent papers will be referred to and distributed during the lectures.

Schedule: please, see Class Schedule

Room: DEI/D meeting room, Dept. of Information Engineering, DEI/D Building, 1st floor (map).

Course requirements: Advanced calculus, and probability theory and random processes.

Examination and grading: A project assignment for students in groups of 2 requiring about 20 hours of work.

IE 16. Imperfect Information and Reasoning

Course Area: Information Engineering

Credits: 5

Instructor: prof. Silvana Badaloni

e-mail: silvana.badaloni@unipd.it

Aim: The course will provide an analysis of different kinds of imperfection that can affect information. In order to represent and reason under imperfect knowledge the fuzzy systems approach will be presented and utilized in many technical applications of Artificial Intelligence.

Topics:

- A classification of some aspects of imperfection affecting knowledge: imprecision, vagueness, inconsistency and uncertainty
- Symbolic representation of knowledge and reasoning
- Fuzzy Sets and Fuzzy Logic
- Mamdani fuzzy inference
- Applications in different fields such as Robotics, Video-surveillance, Smart City applications, Medicine, Machine Learning.

References:

[1] Ph. Smets (1997). Imperfect information : Imprecision - Uncertainty. In A. Motro and Ph. Smets (eds.). Uncertainty Management in Information Systems. From Needs to Solutions, Kluwer Academic Publishers, 225-254.

[2] L.A. Zadeh (1978). Fuzzy sets as a basis for a Theory of Possibility, *Fuzzy Sets and Systems* 1, 3-28.

[3] E.H. Mamdani, S. Assilian (1975). An experiment in linguistic synthesis with a fuzzy logic controller, *International Journal of Man-Machine Studies*, Vol. 7, No. 1, 1-13.

[4] S. Badaloni, M. Giacomin (2006). The Algebra IA^{fuz} : a framework for qualitative fuzzy temporal reasoning. *Artificial Intelligence*, 170, 872-908, Elsevier.

[5] I. Algredo-Badillo, L. A. Morales-Rosales, C.A. Hernandez-Gracidas, E. Cortes-Perez, J. J. Arellano Pimentel (2016). Self-navigating Robot based on Fuzzy Rules
Designed for Autonomous Wheelchair Mobility, *International Journal of Computer Science and Information Security* (IJCSIS), Vol. 14, No. 12.

Class lectures and research papers will be available online for download.

Schedule: please, see Class Schedule

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Room: 318 DEI/G, Dept. of Information Engineering, DEI/G Building, 3rd floor (map).

Course requirements: Basic knowledge of Computer Science.

Examination and grading: Each student will develop a final project, possibly related to his/her research activity, addressing some topic presented in the Course.

IE 17. Big Data Computing: Models and Algorithms

Course Area: Information Engineering

Credits: 5

Instructor: Prof. Geppino Pucci

e-mail: geppino.pucci@unipd.it

Aim: The course tackles fundamental modeling and algorithmic issues posed by big data computing. More specifically, the MapReduce and Streaming processing frameworks are introduced, focussing on which algorithmic design techniques are more amenable to yield effective solutions for a multitude of problems made challenging by high volumes of input data, such as primitives in linear algebra, unsupervised learning, and data and graph analytics.

Topics:

- MapReduce: model, algorithm specification, performance indicators. Basic techniques and algorithmic primitives. MapReduce-inspired processing systems: overview of the Apache Spark ecosystem.
- Streaming techniques for on-the-fly processing of nonpersistent data sequences. Single and multi-pass algorithms, performance indicators. Basic techniques and algorithmic primitives.
- Case studies in linear algebra: space-round tradeoffs for sparse and dense matrix multiplication.
- Case studies in unsupervised learning: center-based clustering algorithms. Clustering as a summarization tool: coreset idea.
- Case studies in data and graph analytics: diversity maximization, diameter and centrality estimations.

References:

[1] J. Dean, S. Ghemawat. MapReduce: simplified data processing on large clusters. Commun. ACM 51(1): 107-113 (2008)

[2] C. Demetrescu and I. Finocchi. Algorithms for data streams. In Handbook of Applied Algorithms, John Wiley and Sons, 2008

[3] A Gentle Introduction to Apache Spark. (From B. Chambers, M. Zaharia. Spark: The Definite Guide, Databricks 2018.)

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[4] A. Pietracaprina, G. Pucci, M. Riondato, F. Silvestri, E. Upfal. Space-round tradeoffs for MapReduce computations. ACM ICS 2012: 235-244.

[5] M. Ceccarello, A. Pietracaprina, and G. Pucci. Improved MapReduce and Streaming Algorithms for k-Center Clustering (with Outliers). CoRR abs/1802.09205 (2018).

[6] M. Ceccarello, A. Pietracaprina, G. Pucci, E. Upfal. MapReduce and Streaming Algorithms for Diversity Maximization in Metric Spaces of Bounded Doubling Dimension. PVLDB 10(5): 469-480 (2017).

[7] Matteo Ceccarello, Andrea Pietracaprina, Geppino Pucci, Eli Upfal. Space and Time Efficient Parallel Graph Decomposition, Clustering, and Diameter Approximation. SPAA 2015: 182-191.

[8] David Eppstein, Joseph Wang. Fast approximation of centrality. SODA 2001: 228-229

Schedule: please, see Class Schedule

Room: DEI/D meeting room, Dept. of Information Engineering, DEI/D Building, 1st floor (map).

Course requirements: Basic knowledge in algorithms and data structures, discrete mathematics, and probability.

Examination and grading: Term paper on a selected subject, also to be presented as a seminar in front of the lecturer and the other class attendees.

IE 18. Elements of Deep Learning

Course Area: Information Engineering

Credits: 5

Instructor: Dr. Gian Antonio Susto, Dr. Chiara Masiero, Dr. Giulia Prando

e-mail: gianantonio.susto@dei.unipd.it, masieroc@dei.unipd.it,

Aim: The course will serve as an introduction to Deep Learning (DL) for students who already have a basic knowledge of Machine Learning. The course will move from the fundamental architectures (e.g. CNN and RNN) to hot topics in Deep Learning research.

Topics:

- Introduction to Deep Learning: context, historical perspective, differences with respect to classic Machine Learning.
- Feedforward Neural Networks (stochastic gradient descent and backpropagation).
- Convolutional Neural Networks.
- Recurrent Neural Networks.
- Applications to Computer Vision, Natural Language Processing, etc.
- Hot topics in current research: Generative Adversarial Neural Networks, Variational Autoencoders, Reinforcement Learning, advanced DL architectures.

References:

[1] Arjovsky, M., Chintala, S., & Bottou, L. (2017). Wasserstein GAN. CoRR, abs/1701.07875.

[2] Bahdanau, D., Cho, K., & Bengio, Y. (2014). Neural Machine Translation by Jointly Learning to Align and Translate. CoRR, abs/1409.0473.

[3] I. Goodfellow, Y. Bengio, A. Courville 'Deep Learning', MIT Press, 2016

[4] Goodfellow, I.J., Pouget-Abadie, J., Mirza, M., Xu, B., Warde-Farley, D., Ozair, S., Courville, A.C., & Bengio, Y. (2014). Generative Adversarial Nets. NIPS.

[5] Hochreiter, S., & Schmidhuber, J. (1997). Long Short-Term Memory. Neural computation, 9 8, 1735-80.

[6] Kalchbrenner, N., Grefenstette, E., & Blunsom, P. (2014). A Convolutional Neural Network for Modelling Sentences. ACL.

[7] Krizhevsky, A., Sutskever, I., & Hinton, G.E. (2012). ImageNet Classification with Deep Convolutional Neural Networks. Commun. ACM, 60, 84-90.

[8] LeCun, Y. (1998). Gradient-based Learning Applied to Document Recognition.

[9] Mikolov, T., Sutskever, I., & Chen, K. (2013). Representations of Words and Phrases and their Compositionality.

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[10] Vincent, P., Larochelle, H., Lajoie, I., Bengio, Y., & Manzagol, P. (2010). Stacked Denoising Autoencoders: Learning Useful Representations in a Deep Network with a Local Denoising Criterion. Journal of Machine Learning Research, 11, 3371-3408.

[11] Zaremba, W., Sutskever, I., & Vinyals, O. (2014). Recurrent Neural Network Regularization. CoRR, abs/1409.2329.

Schedule: please, see Class Schedule

Room: DEI/D meeting room, Dept. of Information Engineering, DEI/D Building, 1st floor (map).

Course requirements: Basics of Machine Learning and Python Programming

Examination and grading: Final project.

IE 19. Massive MIMO – Fundamentals and State-of-the-Art

Course Area: Information Engineering

Credits: 5

Instructor: Prof. Luca Sanguinetti, *Dipartimento di Ingegneria dell'Informazione, Pisa*

e-mail: luca.sanguinetti@unipi.it

Aim: The next generation wireless networks need to accommodate around 1000x higher data volumes and 50x more devices than current networks. Since the spectral resources are scarce, particularly in bands suitable for wide-area coverage, the main improvements need to come from a more aggressive spatial reuse of the spectrum; that is, many more concurrent transmissions are required per unit area. This can be achieved by the Massive MIMO (massive multi-user multiple-input multiple output) technology [1,2], where the access points are equipped with hundreds of antennas and can serve tens of users on each time- frequency resource by spatial multiplexing. The large number of antennas provides a great separation of users in the spatial domain, which is a paradigm shift from conventional multi-user technologies that mainly rely on user separation in the time or frequency domains.

In recent years, massive MIMO has gone from being a mind-blowing theoretical concept to one of the most promising 5G-enabling technologies [3]. Everybody seems to talk about massive MIMO, but do they all mean the same thing? What is the canonical definition of massive MIMO? What are the main differences from the classical multi-user MIMO technology from the nineties? What are the key characteristics of the transmission protocol? How can massive MIMO be deployed? Is pilot contamination an actual problem? Are there any widespread misunderstandings?

These lectures build upon our recent book [4], which provides answers to all of the above questions and aims at giving a clear and balanced picture of the fundamentals of Massive MIMO, as well as an up-to-date survey of the state- of-the-art results in the main areas of spectral efficiency for spatially correlated channels, channel modeling, array deployments, energy efficiency.

Topics:

Massive MIMO: Motivation and Introduction

- Introduction: Trends and 5G goals
- Evolving cellular networks for higher area throughput
- Key aspects of having massive antenna numbers
- Achieving a scalable Massive MIMO protocol

Spectral efficiency

- Basic communication theoretical results
- Methodology for performance evaluation
- Channel estimation
- Spectral efficiency in uplink and downlink
- The limiting factors of Massive MIMO

Asymptotic analysis

- Linearly independent and orthogonal covariance matrices
- Asymptotic Insights
- The unlimited capacity of Massive MIMO
- Acquiring covariance matrices

Practical deployment considerations

- Power allocation
- Spatial resource allocation
- Array deployments – different antenna geometries, effect of antenna element spacing
- Massive MIMO at mmWave frequencies
- Co-existence with heterogeneous networks

Energy efficiency

- Why energy efficiency?
- Transmit power – asymptotic insights
- Mathematical definition of energy efficiency
- Importance of accurate power consumption modeling
- Energy Efficiency and Throughput Tradeoff
- Network Design for Maximal Energy Efficiency

References:

[1] T. L. Marzetta,“Non cooperative cellular wireless with unlimited numbers of base station antennas,”*IEEE Trans. Wireless Commun.*, vol. 9, no. 11, pp. 3590–3600, Nov. 2010.

[2] E. Björnson, J. Hoydis, and L. Sanguinetti, “Massive MIMO has unlimited capacity,” *IEEE Transactions on Wireless Communications*, vol. 17, no. 1, pp. 574–590, Jan 2018.

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[3] S. Parkvall, E. Dahlman, A. Furuskar, and M. Frenne, ``NR: The new 5G radio access technology,'' *IEEE Communications Standards Magazine*, vol. 1, no. 4, pp. 24-30, Dec 2017.

[4] E. Bjornson, J. Hoydis, L. Sanguinetti "*Massive MIMO Networks: Spectral, Energy, and Hardware Efficiency*" Foundations and Trends® in Signal Processing: Vol. 11, No. 3-4, pp 154–655.

Schedule: please, see Class Schedule

Room: DEI/D meeting room, Dept. of Information Engineering, DEI/D Building, 1st floor (map).

Course requirements: Basic knowledge of wireless communications, information theory and probability theory.

Examination and grading: Attendance is required for at least 2/3 of the lecture hours. Final evaluation will be based on the discussion of a case study within the individual PhD project.

IE 20. Power Flow Problem in Transmission and Distribution Networks

Course Area: Information Engineering

Credits: 4

Instructor: Prof. Reza Arghandeh, Western Norway University of Applied Sciences, Norway.

e-mail: rajo@hvl.no

Aim: The course covers power system modeling components. We use open source modeling environment such as OpenDSS. The rest of course will be focused on AC and DC power flow analysis methods using a span of successive approaches including Newton, Gauss, and Sweeping methods for power transmission and distribution networks. The practical challenges for load flow analysis in multi-phase and unbalanced electric grid will be discuss in the course. The is supported by implementing grid model and load flow algorithms in simulation environment.

Topics:

1. Overview the electricity network modeling and matrix-based representation.
2. Load flow analysis:
    a. i) Different analysis methods including Newton, Gauss, and Sweeping.
    b. ii) Load flow in AC vs. DC power systems
    c. iii) Load flow in transmission network vs. distribution networks
3. Load flow analysis implementation issues and numerical examples.
4. Application and validation of load flow algorithm on a realistic electricity network

References:

[1] W. Kersting, Distribution System Modeling and Analysis, CRC, 2014.

[2] L. Powell, Power system load flow analysis, McGraw Hill , 2004.

Class lectures and other material and research papers will be available online for download.

Schedule: please, see Class Schedule

Room: 318 DEI/G, Dept. of Information Engineering, DEI/G Building, 3rd floor (map).

Course requirements: familiarity with basic linear algebra. Knowledge of electric circuits also helps, but it is not a requirement.

Examination and grading: few homeworks and a project to implement load flow algorithm on a IEEE electric feeder model.

IE 21. Heuristics for Mathematical Optimization

Course Area: Information Engineering

Credits: 20 hours

Instructor: prof. Domenico Salvagnin

e-mail: dominiqs@gmail.com

Aim: Make the students familiar with the most common mathematical heuristic approaches to solve mathematical/combinatorial optimization problems. This includes general strategies like local search, genetic algorithms and heuristics based on mathematical models.

Topics:

- Mathematical optimization problems (intro).
- Heuristics vs exact methods for optimization (intro).
- General principle of heuristic design (diversification, intensification, randomization).
- Local search-based approaches.
- Genetic/population based approaches.
- The subMIP paradigm.
- Applications to selected combinatorial optimization problems: TSP, QAP, facility location, scheduling.

References:

[1] Gendreau, Potvin "Handbook of Metaheuristics", 2010

[2] Marti, Pardalos, Resende "Handbook of Heuristics", 2018

Schedule: please, see Class Schedule

Room: DEI/D meeting room, Dept. of Information Engineering, DEI/D Building, 1st floor (map).

Course requirements:

- Moderate programming skills (on a language of choice)
- Basics in linear/integer programming.

Examination and grading: Final programming project.

IE 22. Super-resolution imaging: from physics to data

Course Area: Information Engineering

Credits: 4

Instructor: Enrico Grisan

e-mail: enrico.grisan@unipd.it

Aim: The course will serve as an introduction to the techniques and algorithms to increase the resolution of medical images from low resolution acquisitions, in order to overcome classical physical resolution limits.

Topics:

Introduction to super-resolution imaging: historical perspective, classical approaches, calibration and deconvolution.

I. Probe-based super-resolution
   a. Overview of super-resolution techniques and their computational aspects in optics: STORM, PALM, SIM, SOFI
   b. Translation of probe-based super-resolution to ultrasound: sparse localization, sparse reconstruction and STORM
II. Unsupervised super-resolution
   a. Sparse reconstruction and super resolution; application to MRI
III. Supervised super-resolution
   a. Dictionary learning: applications in microscopy and MRI
   b. Deep learning: applications in microscopy and MRI

References:

[1] *Rust, M.; M. Bates; X. Zhuang* "Sub-diffraction-limit imaging by stochastic optical reconstruction microscopy (STORM)". *Nature Methods.* ***3*** *(10): 793–796, 2006*

[2] *E. Betzig et al. "Imaging Intracellular Fluorescent Proteins at Nanometer Resolution". Science.* ***313*** *(5793): 1642–1645, 2006*

[3] *Gustafsson MG.* "Nonlinear structured-illumination microscopy: Wide-field fluorescence imaging with theoretically unlimited resolution". *Proc. Natl. Acad. Sci. U.S.A.* ***102*** *(37): 13081–6, 2005*

[4] T. Dertinger, R. Coyler, R. Vogel, J. Enderlein, S. Weiss: Achieving increased resolution and more pixels with Superresolution Optical Fluctuation Imaging (SOFI) , Optics Express, Vol. 18 Issue 18, pp. 18875–18885, 2010

[5] K. Christensen-Jeffries et al., In Vivo Acoustic Super-Resolution and Super-Resolved Velocity Mapping Using Microbubbles , IEEE Trans Med Im, 2015

[6] Errico et al. Ultrafast ultrasound localization microscopy for deep super-resolution vascular imaging, Nature volume 527, pages 499–502, 2015

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[7] M Lustig et al. Sparse MRI: The application of compressed sensing for rapid MR imaging, MRM, Volume 58, Issue 6, Pages 1182-1195, 2007
[8] R Timofte et al. A+: Adjusted Anchored Neighborhood Regression for Fast Super-Resolution, ACCV 2014
[9] O. Oktay et al, Multi-input Cardiac Image Super-Resolution Using Convolutional Neural Networks, MICCAI 2016
[10] Zhu, B. et al. Image reconstruction by domain-transform manifold learning. Nature 555, 487–492 (2018)

Schedule: please, see Class Schedule

Room: DEI/D meeting room, Dept. of Information Engineering, DEI/D Building, 1st floor (map).

Course requirements: Basics of Machine Learning, Basics of imaging/computer vision, Matlab programming,

Examination and grading: Final project.

IE 23. Introduction to Information Theory

Course Area: Information Engineering

Credits: 4

Instructor: prof. Deniz Gunduz

e-mail: d.gunduz@imperial.ac.uk

Aim: The aim of this course is to introduce basic information theoretic concepts to students. We will start by introducing entropy, divergence, and, mutual information, and their mathematical properties. The rest of the course will be dedicated to illustrating engineering applications of these seemingly abstract quantities. We will see that entropy corresponds to the ultimate limit in data compression, divergence provides the best error exponent in hypothesis testing (i.e., binary classification), and mutual information sets the limit of how much data one can transmit reliably over a noisy communication channel.

Syllabus

Week 1: Information measures

Day 1: Entropy, divergence, mutual information

Day 2: Properties of information measures (chain rule, data processing inequality, convexity)

Week 2: Lossless data compression

Day 1: Asymptotic equipartition property (AEP)

Day 2: Kraft inequality, Huffman coding and its optimality

Week 3: Information theory and learning

Day 1: Method of types, universal source coding, large deviations: Sanov's theorem

Day 2: Hypothesis testing, Stein's lemma, Chernoff exponent

Week 4: Channel coding

Day 1: Channel capacity theorem, achievability, joint AEP

Day 2: Converse to channel coding theorem, feedback capacity, Joint source-channel coding

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References:

[1] R. B. Ash, *Information Theory*, Dover, 1990.
[2] T. M. Cover and J. A. Thomas, *Elements of Information Theory*, Wiley, 1991.
[3] R. G. Gallager, *Information Theory and Reliable Communication*, Wiley, 1968.

Time table: Course of 16 hours. Class meets on Monday 11:00-13:00 and Tuesday 14:00-16:00 for four weeks starting October 08, 2018, with the exception of the week of Oct. 15 in which the classes will be on Thursday 11:00-13:00 and Friday 14:00-16:00.

Room: DEI/D meeting room, Dept. of Information Engineering, DEI/D Building, 1st floor (map).

Course requirements: Basic knowledge of probability theory will be assumed.

Examination and grading: Grades will be based on a final exam.

SU 1. List of Ph.D. Summer Schools that can be taken for credits

The number of credits earned by participating and taking the final exam is reported only for the Summer Schools whose 2018 program was available at the time of publication of this document. The general rule is that 1 credit is earned every 4 hours of lectures (provided that the final examination is taken and successfully passed).

IMPORTANT NOTE: in order to get credit recognition, students shall hand in the Summer School certificate stating that the student attended the courses and successfully passed the exam to the Ph.D. School Secretariat.

- Summer School in Information Engineering (SSIE)
    - Credits: 5
    - Website 2017: http://ssie.dei.unipd.it
- PhD School of Società Italiana di Elettronica (SIE PhD School)
    - Credits: 5
    - Website 2018: http://sie2018.dieti.unina.it/index.php/phd-school/phd-school-program
- PhD Summer School "Italo Gorini"
    - Credits: 5
    - Website 2018: https://www.gmee.org/gorini2018/program.php
- Ph.D. School in Electromagnetic Security
    - Credits: TBD
    - Date: 7-8 September 2018, Cagliari
    - Website 2018: http://sites.unica.it/rinem2018/
- European Ph.D School: Power Electronics, Electric Machines, Energy Control and Power Systems
    - Credits: 5
    - website 2018: http://www.magento-expert.it/phdschool/phd-school-2018-program/
- Summer School SIDRA (Italian Society of Researchers in Automation)
    - Credits: TBD (normally two Short Courses are offered, 5 credits each)
    - Website 2017: http://sidra2017.dei.unibo.it/
- International Graduate School in Control
    - Offers several one-week (21 hours each)
    - Credits: 5 per course
    - http://eeciinstitute.web-events.net/
- Annual School of Bioengineering
    - Credits: 5
    - Website: http://www.bioing.it/?q=node/35
- IEEE-EURASIP Summer School on Signal Processing

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  - Credits: 5
  - Website: http://s3p2018.cnit.it
- International Computer Vision Summer School
  - Credits: 5
  - Website 2018: http://iplab.dmi.unict.it/icvss2018/Home
- International Summer School on Light Sciences and Technologies
  - Credits: 5
  - Website 2018: http://www.teisa.unican.es/ISLiST