



PhD Courses offered (2016-2017)

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Lab-on-Chip devices: theory, fabrication and applications

Course at a Glance

Basics of Lab-on-Chip technology including design, micro-fabrication and microfluidics. Examples of Lab-on-Chip applications.

Instructors

Salvatore Surdo salvatore.surdo@iit.it

Nanophysics Department, Italian Institute of Technology, Via Morego 30, Genova

Credits: 3

Synopsis

The ability to perform various laboratory procedures on small scale using miniaturized lab-on-chip systems has many benefits. Fluids (e.g. biological samples, reagents) can be precisely controlled; temperature, pH, and concentration control systems as well as a variety of detection systems can be integrated on a portable chip. However, designing and fabrication of lab-on-chip devices is still highly challenging because of their interdisciplinary nature.

The scope of this brief course is to provide the participants with a general understanding of the interdisciplinary field of lab-on-chip systems. We will discuss the different stages of lab-on-a-chip development: design, materials (e.g. silicon, glass and polymer), micro-fabrication, micro-liquid handling, and applications in the life sciences.

This course is intended for PhD students who are interested in getting a better understanding of how miniaturization and microfluidics enable new applications in several fields including analytical chemistry, biomedicine and environmental monitoring. The course illustrates lab-on-chip through a wide range of examples. No prerequisites are required.

Syllabus

The course develops in 10 hours in the classroom.

- General introduction to Lab-on-chip.
- Microfluidics.
- Materials and fabrication techniques.
- Applications.

The examination consists in a written exam.

Reading list

[1] "Microsystem Engineering of Lab-on-a-chip Devices" (Eds. O. Geschke, H. Klank, P. Telleman, Wiley-VCH Verlag GmbH & Co. ISBN 3-527-30733-8)

[2] E. K. Sackmann, A. L. Fulton and D. J. Beebe, The present and future role of microfluidics in biomedical research, Nat. 2014.

[3] S. Haeberle and R. Zengerle, Microfluidic platforms for lab-on-a-chip applications, Lab Chip 2007

Venue:

IIT - Italian Institute of Technology, Via Morego 30, Genova

Course date:

March 2017

Characterization of Polymeric Materials

Course at a Glance

Basic concepts of chemical, physical, and mechanical characterization techniques, with special focus on polymeric bulk and porous materials.

Instructors

Jose Alejandro Heredia-Guerrero jose.guerrero@iit.it

Luca Ceseracciu luca.ceseracciu@iit.it

Javier Pinto Sanz.Pinto@iit.it

Nanophysics Department, Istituto Italiano di Tecnologia

Credits: 6

Synopsis

Bulk and porous polymers are ubiquitous materials in multiple fields of industry and research. Their extensive range of properties facilitates their use in very diverse applications. In this PhD course, we show the main techniques and methodologies in the characterization of their useful properties as materials. This characterization includes the determination of the chemical composition and structure and the potential reactivity as well as the determination of the polymeric structure and its implication on the final properties. In this context, the size and the form of the macromolecules are key parameter.

Furthermore, the application range of polymeric materials can be extended introducing a gaseous phase (porosity), which induces significant modifications on the physical properties of the polymeric samples, controlled by the main parameters of this gaseous phase.

Through a combination of mechanical characterization techniques, it is possible to give a comprehensive description of the deformation mechanisms of polymers, from elastic deformation to plasticity and fracture, taking into account the influence of factors such as temperature, time and scale. The mechanical parameters will include classical uni-axial stress-strain behavior, toughness and fracture toughness, creep, dynamic behavior, hardness, with special focus on nano-indentation.

The objective of this course is to describe the experimental techniques used for these characterizations. The approach is very applied, starting from the theory for each technique and leading to practical strategies to the test design and interpretation of results.

Syllabus

Chemical characterization: main spectroscopy techniques, such as UV/VIS, infrared and Raman spectroscopies and nuclear magnetic resonance;

Structural characterization: the order of the macromolecules in terms of amorphous and crystalline domains will be depicted. Standard methods for the determination of the polymeric structures will be described.

Determination of molecular weight of polymers: the number and weight average molecular weight and the distribution of molecular weights will be explained and the usual methodologies for their determination will be described.

Porous polymers characterization: a brief description of porous polymers production processes and main characteristics will be provided in order to understand the concepts and techniques employed in the course: determination of the main parameters of the porous structure, gas/liquid pycnometry, radioscopy techniques, influence of the porosity on the physical properties of the porous polymers, in-situ study of the processes inducing the porosity.

Mechanical behavior of polymers: deformation mechanisms, uni-axial testing, hardness, toughness measurements

Nano-indentation: fundamentals, analysis methods, practical applications

The examination consists in a written test.

Reading list

- Physical properties of polymers handbook. James E. Mark. Springer.
- Polymer Characterization: Physical Techniques, 2nd Edition. Dan Campbell, Richard A. Pethrick, Jim R. White. CRC Press.
- Cellular Solids: Structure and Properties, 2nd Edition. L. J. Gibson and M. F. Ashby. Cambridge University Press.
- Nanoindentation, 2nd ed., A. C. Fischer-Cripps, Springer

Course date :

April 2017

Advanced Optical Fluorescence Microscopy Methods I

Course at glance

Advanced Optical Fluorescence Microscopy deals with this optical methods based on fluorescence that can also benefit of integration with scanning probe microscopy or other optical mechanisms of contrast towards investigations in biophysics, biomedical engineering and materials science.

Instructor

Alberto Diaspro Alberto.diaspro@iit.it
Nanophysics, Istituto Italiano di Tecnologia
Tel: +39 010 71 781 503

Credits: 3

Synopsis

This course considers, as starting point, those implementations in advanced optical fluorescence microscopy (AOFM) that allow to get 4D(x-y-z-t) information like computational optical sectioning microscopy (COSM), confocal laser scanning microscopy (CLSM), two-photon excitation microscopy (2PEM) and light sheet fluorescence microscopy (LSFM). The course will consider theoretical and experimental aspects within a critical discussion related to focused applications. Variations on the theme will be treated by considering the possibility of getting complementary information by including Second Harmonic Generation, Light Scattering Polarization and Force interaction measurements in AOFM schemes. A possible route to bring such approaches to super resolution methods will be critically discussed.

Syllabus

The Course develops in about 9 hours in the classroom.

- Spatial and Temporal Resolution in image formation (spatial and frequency domain)
- Laser sources
- Critical discussion related to the biological, medical or materials science question
- Overview of microscopy methods

The examination consists in a journal club based on a selected list of papers provided to the students

Reading list

Please refer to the Educational Program Section of the NIC@IIT - <http://www.nic.iit.it/education-program-training/>

Notes by Alberto Diaspro will be available at the Course

Specific textbooks for this Course are:

- A.Diaspro (ed.), *Confocal and Two-Photon Microscopy: Foundations, Applications and Advances*, Wiley (2001)
- A.Diaspro (ed.) *Optical Fluorescence Microscopy*, Springer (2011)
- A.Diaspro (ed.) *Nanoscopy and Multidimensional Optical Fluorescence Microscopy*, Taylor and Francis/C Chapman and Hall/CRC (2009)
- J.Pawley (ed.) *Handbook of Confocal Microscopy*, Springer (2006)
- C.J.R Sheppard and D.Shotton, *Confocal Laser Scanning Microscopy*, Garland Science (1997)

Venue

IIT - Via Morego, 30 16163 Genova

Course date

June 2016

Advanced Optical Fluorescence Microscopy Methods II

Course at glance

Advanced Optical Fluorescence Microscopy 2 deals with quantitative fluorescence microscopy and spectroscopy techniques that are of interest for investigators in biophysics, biology, biomedical engineering and materials science.

Instructor

Luca Lanzanò

luca.lanzano@iit.it

Credits: 3

Synopsis

This course considers, as starting point, fundamental aspects of fluorescence spectroscopy (absorption/ emission spectra, lifetime, energy transfer, intensity fluctuations, etc) that are the basis of advanced fluorescence microscopy techniques. An overview of quantitative fluorescence-based methods, including Forster Resonance Energy Transfer (FRET), Fluorescence Lifetime Imaging (FLIM), Fluorescence Correlation Spectroscopy (FCS), will be the core of the course. The course will focus on the principles, the experimental aspects and examples of applications of the techniques. The methods of analysis will also be discussed.

Syllabus

The Course develops in about 9 hours in the classroom.

- Quantitative Fluorescence Spectroscopy
- Overview of advanced fluorescence spectroscopy/microscopy methods
- Critical discussion related to the biological, medical or materials science questions

Final examination: to be defined

Specific textbook for this Course:

- Molecular Fluorescence: Principles and Applications, Bernard Valeur, Wiley-VCGH Verlag GmbH

Venue

IIT - Via Morego, 30 16163 Genova

Course date

May 2015

Laboratory of Optical Fluorescence Microscopy Methods

Course at glance

The practical course will introduce at the use of the most advanced and modern microscopy techniques, using the microscopes at the Nikon Imaging Center (NIC@IIT).

Instructor

Marta D'Amora marta.damora@iit.it

Tel: +39 010 71 781 290

Nanophysics, Istituto Italiano di Tecnologia

Credits: 3

Synopsis

The goal of the course is to teach and train fundamental knowledge and skills in microscopy. Students will learn how to apply these techniques to their own present and future projects. Practical work consists of 4 different modules covering a specific technique/topic (see syllabus). Students will participate to all practical modules. For the practical training the students will use the most state-of-the-art instrumentation. Such an instrumentation is able to cover all the fundamental needs of modern biology, namely high temporal and/or spatial resolution, live cell imaging and multimodal microscopy. A fundamental step for the success of super resolution experiments relay on the sample preparation. Nevertheless, these protocols preparation show many common aspects with standards protocols, some critical steps need to be added. These critical steps will be discussed in the course.

Syllabus

The Course develops in about 9 hours in the lab.

Hands on:

- Time lapse
- Spinning disk
- Confocal A1 Nikon
- SIM and/or STORM

The examination consists in a report on the experiments carried on during the course.

Reading list,

Please refer to the Educational Program Section of the NIC@IIT - <http://www.nic.iit.it/education-program-training/>

Specific textbooks for this Course are:

- A.Diaspro (ed.), Confocal and Two-Photon Microscopy: Foundations, Applications and Advances, Wiley (2001)
- A.Diaspro (ed.) Optical Fluorescence Microscopy, Springer (2011)
- A.Diaspro (ed.) Nanoscopy and Multidimensional Optical Fluorescence Microscopy, Taylor and Francis/cHapmann and Hall/CRC (2009)
- J.Pawley (ed.) Handbook of Confocal Microscopy, Springer (2006)

Venue

NIC@IIT, IIT - Via Morego, 30 16163 Genova

Course date

June 2017

Optics and Imaging in Modern Microscopy

Course at glance

There have recently been great advances in instruments and techniques for microscopy, especially for biological and medical research and diagnostics. The course reviews the basic optical and imaging principles that form the basis of modern microscopy. Different microscopy modalities are introduced, including those based on fluorescence, and also label-free methods based on phase, polarization or non-linear optical properties.

Instructor

Colin Sheppard colin.sheppard@iit.it

Tel: +39 010 71 781 804

Nanophysics, Istituto Italiano di Tecnologia

Credits: 3

Synopsis

This course introduces the optics necessary to investigate the common properties of imaging systems, including the physical principles, hardware and algorithms. Applications in the biomedical area are stressed, but other applications range from remote sensing, geophysical imaging, nondestructive testing and machine vision.

Syllabus

The Course develops in about 9 hours in the classroom.

Diffraction and focusing; effects of numerical aperture, polarization and Fresnel number. Microscopy concepts. Coherent and incoherent imaging; transfer functions, Abbe imaging theory, illumination system, imaging performance, microscope objectives, partially-coherent imaging. The generalized microscope. Phase contrast; defocus, dark field, Zernike phase contrast, differential phase contrast. Polarization imaging. Confocal microscopy and imaging; principles and instruments. surface profiling. image formation in the confocal microscope. Fluorescence microscopy; detectors, signal, signal-to-noise ratio, comparative performance of imaging systems. Super resolution in microscopy. Advances in pupil filters. Three-D imaging; 3D transfer functions, holography and tomography. Three-dimensional imaging techniques; interference microscopy and OCT, multiphoton imaging, fringe projection. Image modeling and reconstruction; tomography, Born and Kirchhoff approximations.

The examination consists in a journal club based on a selected list of papers provided to the students

Reading list

Please refer to the Educational Program Section of the NIC@IIT - <http://www.nic.iit.it/education-program-training/>.

Notes by Colin Sheppard will be available at the Course.

Specific textbooks for this Course are:

- E. Hecht, Optics, Addison Wesley (2002)
- A.Diaspro (ed.), Confocal and Two-Photon Microscopy: Foundations, Applications and Advances, Wiley (2001)
- J.Pawley (ed.) Handbook of Confocal Microscopy, Springer (2006)
- C.J.R Sheppard and D.Shotton, Confocal Laser Scanning Microscopy, Garland Science (1997)

Venue

IIT - Sala Montalcini-Auditorium - Via Morego 30, 16163 Genova

Course date

March 2017

Super-resolution Optical Fluorescence Microscopy

Course at a Glance

Far field fluorescence super-resolution microscopy, from theory to applications. The course will be focused on the concept behind fluorescence super-resolution microscopy with particular attention to single molecule localization techniques (SML). Furthermore basics principles of structured illumination SIM, RESOLFT, STED and Expansion microscopy will be also explained.

Instructor

Francesca Cella Zanicchi francesca.cella@iit.it

Tel: +39 010 71 781 320

Nanophysics, Istituto Italiano di Tecnologia

Credits: 3

Synopsis

Breakthrough in optical microscopy and labeling techniques opened new possibilities in the investigation of protein organization and dynamics in biological systems. The recent development of super-resolution microscopy played a relevant role in the groundbreaking progress in life science and neuroscience. In particular, state-of-the-art far field super-resolution microscopy techniques based on single molecule localization not only provide imaging capabilities with unprecedented resolution, but they also represent a powerful tool to quantify protein distribution and “count” molecules in biological system.

This course will explain the basics of super-resolution techniques. Particular attention will be addressed to Single Molecule Localization Microscopy Techniques (SML) and Light sheet fluorescence microscopy. Basics principles of super-resolution techniques based (such as Structured illumination SIM, RESOLFT, STED and Expansion microscopy) will be also explained.

Syllabus

The course develops in about 7 hours in the classroom and 2 hours of laboratory activity.

- Individual Molecule localization techniques: F-PALM, PALM, STORM.
- Single molecule Tracking
- Light sheet microscopy and super-resolution: SPIM, DSLM, Inclined Illumination and IML-SPIM
- Structured Illumination microscopy (SIM) and saturated SIM (SSIM)
- Reversible Saturable Optical Fluorescence Transitions (RESOLFT) and stimulated emission microscopy STED

The examination consists in a journal club or a brief research project proposal.

Reading list

- Hell S.W., “Microscopy and its focal switch”, Nat. Methods, 6, 24-32 (2009)
- E. Betzig et al. (2006). "Imaging Intracellular Fluorescent Proteins at Nanometer Resolution". Science 313 (5793)
- Deschout, H., et al., Precisely and accurately localizing single emitters in fluorescence microscopy. Nat Methods. 11(3): p. 253-66 (2014).
- Francesca Cella Zanicchi et al. “Live-cell 3D super-resolution imaging in thick biological samples” Nature Methods 12/2011
- Vicidomini G. et al., “Sharper low-power STED nanoscopy by time gating”, Nat. Methods, 8, 571-573 (2011)

Venue

IIT - Via Morego, 30 16163 Genova

Course date

April 2017

Course date

June 2016

Laser-matter interactions: from fundamentals to applications

Course at a Glance

Physics of lasers, properties of laser radiation and basic fundamentals of light-matter interactions with examples of key laser-based applications.

Instructors

Martí Duocastella

Nanophysics Department, Italian Institute of Technology, Via Morego 30, Genova

e-mail: marti.duocastella@iit.it

tel: 010-6475206

Credits: 4

Synopsis

Lasers have become ubiquitous in our daily lives. From DVD players to bar code scanners, printers, or even in medicine, laser-based applications are countless. Not to mention the pivotal role that lasers are playing in science and in state of the art industrial processes. But what are the characteristics of lasers that make them so broadly used?

In this brief course we will answer this question by describing the physics of laser systems and the properties of laser radiation. We will also explain the basic interactions between laser light and materials, and we will give examples of applications where lasers are the enabling technology.

This course is intended for PhD students who anticipate working with lasers. No background in lasers is required. Emphasis is placed on the physical interpretation of lasers and on their applications, with mathematics kept at a minimum.

Syllabus

The course develops in 12 hours in the classroom.

- Fundamentals of lasers: lasers, laser radiation characteristics, laser types
- Interaction of lasers with materials: absorption, dispersion, photophysical processes, photochemical processes
- Lasers at IIT: 3D microfabrication, nanoparticle generation, photolithography, surface structuration, optical characterization

The examination consists in a brief research project proposal or in an oral presentation.

Reading list

- D. Bauerle, Laser Processing and Chemistry, Springer, 2011 ISBN: 978-3-642-17613-5
- S. Ezekiel, Understanding lasers and fiberoptics, MIT Open Course <http://ocw.mit.edu/resources/res-6-005-understanding-lasers-and-fiberoptics-spring-2008/>

Venue

IIT

Course date

July 2017

Brain Connectivity Analysis

Course at a Glance

The present course will introduce the student to the field of Brain Connectivity, presenting the methods currently used in neuroimaging studies. The course will focus on the three classes in which Brain Connectivity is traditionally divided, namely *structural*, *functional* and *effective* connectivity.

Instructors

Gabriele Arnulfo gabriele.arnulfo@unige.it

Andrea Canessa andrea.canessa@unige.it

Credits: 4

Synopsis

A central paradigm in modern neuroscience is that anatomical and functional connections between brain regions are organized in a way such that information processing is near optimal. Functional interactions seem to be provided by synchronized activity, both locally and between distant brain regions. Brain networks thus consist of spatially distributed but functionally connected regions that in concert process information. Brain connectivity analysis rests upon three different but related forms of connectivity: *structural*, *functional* and *effective*.

The course is organized as follow. First, the student will be introduced to the so called structural connectivity and white matter fibre tracts representing the anatomical backbone for functional and effective connectivity. A representative selection of algorithms in use in diffusion-weighted MRI (dwMRI) will be presented. Then recent computational methods dealing with functional connectivity and some illustrative applications are reported. This is followed by a short survey of recent studies on effective connectivity. Finally, the course will discuss the important concepts of graph theory and their application to brain networks characterization. The course is not meant to be comprehensive; rather it should illustrate some prototypical studies in this field and provide the students with basic methods and critical understanding to autonomously carry out brain connectivity studies.

Tools used:

Software

- Matlab (toolbox Brainstorm, EEGLAB, Fieldtrip)

Syllabus

- Brain Connectivity fundamentals: physics and physiology.
- Neural Mass Models.
- Structural Connectivity.
- Functional Connectivity.
- Effective Connectivity.
- Graph theory.

Final exam

There will be a final examination decided by the instructors.

Prerequisites

Good knowledge of Matlab

Reading List

All papers written by these expert authors in the field

- Breakspear, M.
- Bullmore, E.
- Buszàki, G.
- Deco, G.
- Friston, K.
- Jirsa, V.
- McIntosh, R.
- Nolte, G.
- Palva, M.J.
- Sporns, O.
- Wibrall, M.
-

Venue

DIBRIS, Villa Bonino, Viale Causa 13, Genova

Course dates

September 2017

C++ Programming Techniques

Course at a Glance

An overview of the object oriented programming concepts using the C++ language.

Instructors

Manuela Chessa manuela.chessa@unige.it

DIBRIS, via Dodecaneso 35; room 226, phone: 010-353 6626

Fabio Solari fabio.solari@unige.it

DIBRIS, via Dodecaneso 35; room 303, phone: 010-3536756

Credits: 5

Synopsis

This course focuses on the use of C++ for large software projects and for the implementation of high performance object-oriented modules. In particular, programming techniques to tackle the issues of reusability, robustness and efficiency are considered.

Tools used:

Software

- C++ compiler

Syllabus

- Basic Facilities: The C and C++ languages: pointers, arrays, and structures. Functions. Namespaces and exceptions.
- Abstraction Mechanisms: Classes and objects. Operator overloading. Class hierarchies. Polymorphism. Templates.
- Case studies: Containers and algorithms. Iterators.

Final exam

The examination consists in the development (with discussion) of a specific software module.

Prerequisites

Knowledge of a programming language.

Reading List

- B. Stroustrup. The C++ Programming Language. Addison-Wesley
- B. Eckel. Thinking in C++. Prentice Hall

(<http://www.mindview.net/Books/TICPP/ThinkingInCPP2e.html>)

Venue

Dept. of Informatics, Bioengineering, Robotics and System Engineering - DIBRIS, via Dodecaneso 35, Genova

Course dates

June-July 2017

Electric circuits for Electrochemistry

Course at a Glance

The aim of this course is to give an introduction to the electric circuit theory and to the electrochemical techniques in order to allow the students to correctly perform and interpret the measurements. The course will start from lumped circuits basics and moving through transient and frequency analyses of linear circuits. Basics of electrochemical measurements and typical measurement configurations will be introduced. Finally, lumped element modelling of typical equivalent circuits will be discussed and examples of simulations by common tools (Spice, EC-Lab) will be performed. The course will comprehend some hands on experience on potentiostat and battery analyser as well.

Instructors

Alberto Ansaldo alberto.ansaldo@iit.it
Simone Monaco simone.monaco@iit.it

Credits: 5

Synopsis

- Introduction to electric circuits
- Electrical measurements
- Introduction to electrochemistry
- Electrochemical systems modelling and simulation
- An introduction to EC-Lab

Tools used:

Hardware

- Bioscope potentiostat/galvanostat/battery analyser

Software

- LT-Spice
- EC-lab

Syllabus

The course covers all the aspect of circuit modelling significant for electrochemical circuits modelling in order to allow a comprehensive understanding of both the electrical and the chemical aspects involved.

First part: Introduction to electric circuits

- Lumped element circuits
- Kirchhoff laws
- Basic lumped elements
- Examples of typical electric circuits
- Nyquist (Cole Cole) and Bode plots
- Transient response and frequency response of LCR circuits
- Introduction to the distributed models
- Generalised lumped elements

Second part: Electrical measurements

- Typical instruments and measurement configurations
- The potentiostat/galvanostat
- Examples of typical measurements mistakes

Third part: Introduction to electrochemistry

- The electrochemical cell
- Reference electrodes
- Electrochemical cell measurement configurations
- Introduction to electrochemistry (second part - 2h)
- Impedance spectroscopy
- Cyclic voltammetry
- Differential pulse voltammetry

Fourth part: Electrochemical systems modelling and simulation

- Typical circuits
- Extraction of lumped parameters from transient response and frequency response of physical systems (black box approach)
- Electrochemical lumped elements (CPE, Warburg, etc...)
- Introduction to circuit modelling and simulation by Spice (LTspice)
- The potentiostat: a simulated model
- Examples of the influence of the electrical parameters on the typical electrochemical measurements.
- The examination consists in discuss and simulate a typical electrochemical measurement.

Fifth part: An introduction to EC-Lab

- the EC-lab user interface
- typical measurement and data representations
- data analysis and simulation tools

Final exam

The examination consists in discuss and simulate a typical electrochemical measurement.

Reading List

- Basic Circuit Theory, Charles A. Desoer and Ernest S. Kuh, McGraw Hill, New York, 1969.
- Linear and Nonlinear Circuits, Leon O. Chua, Charles A. Desoer and Ernest S. Kuh, McGraw Hill, New York, 1987.
- Analytical Electrochemistry, Joseph Wang, John Wiley & Sons, 2006.

Venue

Istituto Italiano di Tencologia- Via Morego, 30 16163 Genova

Course dates

February-May 2017

Introduction to Computer Programming for Researchers

Course at a Glance

The course will take the students with no or minimal prior experience of programming through the main principles and best practices of programming. Particular attention will be devoted to the use of instruments useful to the researcher to carry out their work, such as to programming languages like Matlab and Python.

Instructors

Marcello Goccia (marcello.goccia@iit.it)

Credits: 5

Synopsis

This course is designed to be an entry level programming course which provides the instruments for the researchers to carry out their work, paying particular attention to programming languages like Matlab and Python. The course is suitable for students who have minimal or no programming experience. It will introduce the fundamental programming structures, and it will also cover some central mechanisms of object-oriented programming techniques. The course will also include an introduction to testing and debugging code techniques. During the course there will be practical exercises.

Tools used:

Hardware

- Bring a laptop with you

Software

- Python 3 and Matlab installed

Syllabus

- Overview of the fundamental programming structures: primitive data types, constants, variables, operators, functions, strings.
- Classes and objects: OOP principles, class variables and methods, abstraction, inheritance, polymorphism.
- Introduction to good programming techniques.
- Testing and debugging code.
- Practical exercises

Final exam

There will be a final examination decided by the instructor

Prerequisites

The course is aimed at students with little or no prior programming experience.

Venue

Istituto Italiano di Tecnologia, Via Morego 30, Bolzaneto, Genova

Course dates

May 2017

Artificial Cognitive Systems

Course at a Glance

This course will provide an intensive introduction to the emerging field of artificial cognitive systems. Inspired by artificial intelligence, developmental psychology, and cognitive neuroscience, the aim is to build systems that can act on their own to achieve goals – perceiving their environment, anticipating the need to act, learning from experience, and adapting to changing circumstances – and interact with other agents, including humans.

Instructors

David Vernon david@vernon.eu

Hours and Credits

10 hours (lectures) 3 credits

Synopsis

We begin by examining what is meant by the term *cognition*. This allows us to develop a working definition of cognition and cognitive systems, one that strikes a balance between being broad enough to do service to the many views that people have on cognition and deep enough to help in the formulation of theories and models. We then survey the different paradigms of cognitive science to establish the full scope of the subject. We follow this with a discussion of cognitive architectures before tackling the key issues: autonomy, embodiment, learning & development, memory & prospection, knowledge & representation, and social cognition.

Tools used:

Hardware

Not applicable

Software

Not applicable

Syllabus

The nature of cognition: models, definitions, autonomy, Marr's levels of abstraction.

Paradigms of cognitive science: cognitivism, emergent systems, and hybrid systems.

Cognitive architectures: cognitivist, emergent, and hybrid architectures, desirable characteristics, example cognitive architectures.

Autonomy: robotic, biological, behavioural, & constitutive autonomy, homeostasis, self-maintenance, continuous reciprocal causation, autonomic systems.

Embodiment: the three hypotheses, the mutual dependence of perception and action, off-line embodied cognition, situated, embedded, grounded, extended, and distributed cognition.

Development and learning: motives, imitation, supervised, unsupervised, and reinforcement learning, phylogeny and ontogeny, developmental psychology.

Memory and prospection: short-term, long-term, declarative, procedural, semantic, episodic, symbolic, sub-symbolic, internal simulation, prospection.

Knowledge and representation: memory and knowledge, representation, anti-representation, sharing knowledge, radical constructivism, symbol grounding, learning from demonstration.

Social cognition: interaction, intentionality, theory of mind, instrumental helping, collaboration, joint action, shared intention, shared goals, joint attention, development and interaction dynamics.

Final exam

There will be a final examination decided by the instructors.

Prerequisites

None.

Reading List

Vernon, D. Artificial Cognitive Systems – A Primer, MIT Press, 2014.

Venue

Istituto Italiano di Tecnologia
Via Morego, 30
16163 Genova

Course dates

5-6 December 2016

Remarks

Organized in collaboration with Prof. Giulio Sandini and Dr. Alessandra Sciutti.

Nano-plasmonic devices: from fabrication to applications

Course at a Glance

Introduction to nanofabrication: top-down and bottom-up approaches for the realization of plasmonic devices.

Instructors

Andrea Toma andrea.toma@iit.it

Tel: 010 71781257

Istituto Italiano di Tecnologia

Credits: 3

Synopsis

The fabrication of complex plasmonic nanostructures integrated in innovative device architectures represents a multidisciplinary key activity at the core of most research efforts in nanoscience and technology. In particular, the possibility to promote giant field enhancement has gained increasing attention over the last few years, enabling the detection of molecules in highly diluted liquids, and/or the spectral signature collection of single/few molecules concentrated in nanovolumes. The “hot spot” concept, induced by localized surface plasmon resonances (LSPR), will be introduced as core idea behind the surface-enhanced infrared absorption (SEIRA) and the surface-enhanced Raman spectroscopy (SERS). Within this context, we will pay attention to the state of the art nanofabrication technologies, e.g. following top-down or bottom-up methods. In details, top-down fabrication refers to approaches such as electron beam lithography (EBL) or focused ion beam lithography (FIB) where focused electrons or ions are used to carve nanostructures into macroscopically dimensioned materials. Alternatively, in the bottom-up approach, one begins to assemble nanostructures from smaller units. Examples will include colloidal synthesis and unfocused ion beam sputtering.

Tools used:

Software

- Brief introduction to Monte Carlo simulations of electron and ion collisions in solids. Stopping powers, range and straggling distributions for ions and electrons in multilayer target will be calculated *via* CASINO (<http://www.gel.usherbrooke.ca/casino/>) and SRIM (<http://www.srim.org>) software packages.

Syllabus

- Nanofabrication technologies: top-down and bottom-up approaches for the realization of next- generation devices.
- Nano-plasmonic devices: design and realization of ultrasensitive biosensors. ^[1]_[SEP]
- SEIRA and SERS: employing plasmonic devices for the ultrasensitive detection both in the visible and in the infrared range. ^[1]_[SEP]

Final exam

The examination consists in a journal club or a brief research project proposal.

Reading List

- R. Aroca, Surface-Enhanced Vibrational Spectroscopy, Wiley (2006).
- S. Maier, Plasmonics: Fundamentals and Applications, Springer (2007).

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- M. Jackson, Micro and Nanomanufacturing, Springer (2007).
- R. Kelsall, I. W. Hamley, M. Geoghegan, Nanoscale Science and Technology, Wiley (2005).

Venue

Istituto Italiano di Tecnologia - Via Morego 30, 16163 Genova

Course dates

September – October 2017

Introduction to physical Human-Robot Interaction

Course at a Glance

The present course will introduce the field of physical Human-Robot Interaction (pHRI). It will discuss current scientific and technological limitations in collaborative scenarios and methods to deal with them. Emphasis will be given to the integration of knowledge between neuroscience and robotics.

Instructors

Jacopo Zenzeri jacopo.zenzeri@iit.it

Credits: 3

Synopsis

Robotic technology is rapidly developing, and seemingly offers a multitude of potential near-future applications. We see robots as *embodied* artificial intelligence (AI), and although AI is progressing rapidly in many areas, generating efficient movement and physical interaction is still a major challenge, especially when it comes to human-like movement and interaction with humans. In line with these considerations, in the next years the field of physical human-robot interaction will be extensively studied both from human and robot side. Specific robots will be designed to cooperate with humans in different contexts such as assisted industrial manipulation, virtual training, entertainment or rehabilitation.

The first part of the course will introduce basic concepts on how the brain control movements in humans and how it is possible to design robot control strategies for interacting robots. In the second part of the course will be presented findings in collaborative scenarios both from robot and human perspective.

Syllabus

- The concept of physical human robot interaction
- Human motor control strategies and mechanisms
- Robot control in pHRI: Compliance control, Impedance control, Force control
- Human motor skill learning during haptic interaction
- Robot learning algorithms in collaborative contexts

Final exam

There will be a final examination scheduled with each student.

Prerequisites

None

Reading List

Specific readings will be assigned for each class.

Venue

Istituto Italiano di Tecnologia, Via Morego 30, 16163, Genova

Course dates

November - December 2017

Robotic technologies for sensorimotor rehabilitation

Course at a Glance

The course will present the different concepts underlying robotic rehabilitation. It will discuss the limitation of conventional physical therapy and the potential of robotics in the field of rehabilitation. Emphasis will be given both in technological and neuroscientific aspects related to the recovery of impaired patients.

Instructors

Jacopo Zenzeri jacopo.zenzeri@iit.it

Pietro Morasso pietro.morasso@iit.it

Credits: 4

Synopsis

Rehabilitation robotics is the application of robots to overcome disabilities and improve quality of life after brain injuries. In contrast with other areas in robotics, this course considers not only engineering design and development, but also the human factors that make some innovative technologies successful.

The first part of the course will deal with the clinical and neuroscientific aspects related to the rehabilitation. The second part will analyze the technological characteristics needed to design robots able to interact with humans.

Ultimately, the last part will present examples on how the two parts can be combined in order to optimally design robots and the related rehabilitation protocols to effectively improve subjects' recovery process.

Syllabus

- The concept of robotic rehabilitation
- Conventional rehabilitation techniques
- Neural plasticity and sensorimotor functions
- Robots for rehabilitation: manipulators, exoskeletons
- Possible control strategies: assistive, passive, active
- Case studies and future trends

Final exam

There will be a final examination decided by the instructors.

Prerequisites

None

Reading List

Specific readings will be assigned for each class.

Venue

Istituto Italiano di Tecnologia, Via Morego 30, 16163, Genova

Course dates

October – November 2017

An Introduction to Spatial (6D) Vectors and Their Use in Robot Dynamics

Course at a Glance

This course provides an introduction to spatial vector algebra, which simplifies the task of solving problems in rigid-body dynamics by reducing the number of quantities and equations that are needed. The course also covers the most important recursive dynamics algorithms: the Recursive Newton-Euler, Composite-Rigid-Body and Articulated-Body algorithms.

Instructors

Roy Featherstone roy.featherstone@iit.it

Hours and Credits: 5

Synopsis

Spatial vectors combine the linear and angular aspects of rigid-body motion, so that a single vector can provide a complete description of a body's velocity, acceleration, momentum, or the forces acting upon it. The result is a large reduction in the quantity of algebra needed to describe and solve a problem in rigid-body dynamics: fewer quantities, fewer equations, and fewer steps to the solution. There is also a large reduction in the quantity of computer code needed to calculate the answer. This course explains spatial vectors in sufficient detail to allow students to understand what they are, how they work, and how to use them in their own research.

Tools used:

Software

- Matlab and Simulink
- spatial_v2 (available from <http://royfeatherstone.org>)

Syllabus

- Motion and force
- Plucker coordinates
- Differentiation and acceleration
- Equation of motion
- Motion constraints
- Dynamic models
- Inverse dynamics – recursive Newton-Euler algorithm
- Forward dynamics – composite-rigid-body and articulated-body algorithms

Final exam

There will be a final examination for those students who wish to receive credits for this course.

Prerequisites

A basic knowledge of Newtonian dynamics is required (i.e., dynamics using 3D vectors), such as can be obtained from a first course in dynamics at undergraduate level. A basic knowledge of linear algebra is also required.

Reading List

The book *Rigid Body Dynamics Algorithms* (Springer, 2008) covers the material in this course in much greater depth, and is recommended for those students who wish to make serious use of spatial vectors. Otherwise, several useful items can be found on <http://royfeatherstone.org/spatial/>.

Venue

IIT via Morego

Course dates

March 2017

Tissue Engineering: Cells, Biomaterials and Bioreactors

Course at a Glance

Basic concepts to generate engineered grafts for clinical and/or research regenerative medicine applications

Instructors

Silvia Scaglione silvia.scaglione@ieiit.cnr.it

Tel: 010 647 5206

Istituto di Elettronica e di Ingegneria dell'Informazione e delle Telecomunicazioni (IEIIT), Consiglio Nazionale delle Ricerche (CNR) - Via De Marini, 6, 16° floor

Credits: 5

Synopsis

Tissue Engineering is an multidisciplinary field involving biology, medicine, material science and bioengineering aimed to improve the health and quality of life for millions of people worldwide by restoring, maintaining, or enhancing tissue and organ function. Tissue engineering research includes the following areas: (i) Biomaterials: including novel biomaterials designed to direct the organization, growth, and differentiation of cells in the process of forming functional tissue by providing both chemical and physical (macro-micro-nano scale) cues. (ii) Cells: including enabling methodologies for the proliferation and differentiation of cells, acquiring the appropriate source of cells such as autologous cells, allogeneic cells, xenogeneic cells, stem cells, genetically engineered cells, and immunological manipulation. (iii) Biomolecules: including growth factors, differentiation factors, angiogenic factors, their synthesis and their release. (iv) Engineering Design Aspects: including 3D tissue growth, modeling of scaffold internal architecture, bioreactors to offer specific stimulation to living tissues, design of organ on chip technologies. (v) Biomechanical Aspects of Design: including properties of native tissues, identification of minimum properties required of engineered tissues, mechanical signals regulating engineered tissues, and efficacy and safety of engineered tissues. (vi) Informatics to support tissue engineering: gene and protein sequencing, gene expression analysis, protein expression and interaction analysis, quantitative tissue analysis, in silico tissue and cell modeling

Syllabus

The course develops in about 15 hours in the classroom.

- Cell-Based Therapies for TE: methodologies for isolation, differentiation, selection of adult progenitors/stem cells.
- Biomaterials for TE: design of intelligent materials; study of the proper macro-micro-nano-structures, chemical compositions, biomechanical properties; cell-biomaterials interfaces, bioactivation of surfaces.
- Bioreactor systems for TE: perfusing bioreactor systems, biomechanical stimulating bioreactors, fluido-dynamic stimulating bioreactors.
- Pre-clical/Clinical models: in vivo case studies, implant of cell-biomaterials constructs, animal models.

The examination consists in a journal club or a brief research project proposal.

- Reading list

- Jeffrey A. Hubbell 1995 "Biomaterials in Tissue Engineering" *Nature Biotechnology* **13**, 565 - 576

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- Ivan Martin, David Wendt and Michael Heberer 2004 “The role of bioreactors in tissue engineering” Trends in Biotechnology 22(2): 80-86
- Paolo Bianco & Pamela Gehron Robey 2001 “Stem cells in tissue engineering” Nature 414, 118-121
- Sangeeta N Bhatia & Donald E Ingber 2014 “Microfluidic organs-on-chips” Nature Biotechnology 32, 760–772
- Tal Dvir, Brian P. Timko, Robert Langer 2010 “Nanotechnological strategies for engineering complex tissues” Nature Nanotechnology 6, 13–22

Venue

(CNR) - Via De Marini, 6, 16° floor

Course date

March- April 2017

Robotic Virtual Prototyping Design

Course at a Glance

The aim of the Robotic Virtual Prototyping Design course is to give the basic knowledge about the Finite Element Analysis (FEA) and Multi-Body Simulations (MBS) applied to the robotics. These computational techniques predict the behaviour of physical systems: joined together permit to study the dynamics taking in account the body flexibility, the control and optimisation. It will be introduced mainly applied to the mechanical field, in particular to the robotic anthropomorphic arm. The student gets 5 credits if he/she attends the entire course and accomplishes the final project.

Instructors

Ferdinando Cannella ferdinando.cannella@iit.it

Mariapaola D'Imperio mariapaola.dimperio@iit.it

Credits: 5

Synopsis

Virtual Prototyping Design is the basic part of the Computer Aided Engineering (CAE) that in the last decades involved more and more the R&D of the industries and the Research Centres. The reason is that the physical models need more time and energies for being improved than virtual ones. Moreover, running numerous simulations, these models permit to be optimized depending on several parameters.

Thus the course will give an overview on the virtual prototyping design building the models with the main software (MSC.Nastran, Ansys/Workbench and MSC.Adams). In the second part of the course, Multibody and Finite Element Analysis will be integrated in order to take the best advantage from the virtual prototyping technique and applied to some mechanisms and robot arms. Then the control (Matlab/Simulink) and the optimization (ModeFRONTIER) will be applied to the simulations.

Even if the training solutions concern the mechanical and robotic problems, it is designed to provide to attendants with both the comprehensive and subject-specific knowledge; the students need to effectively apply software tools to solve general problems: static, dynamic, linear, non-linear and motion or multi-physics analysis. So the aim of the course is not only knowing the performances of the software used to build the basic models, but it is also to be able to improve their skill by themselves.

Tools used:

Software

- MatLab, SimuLink
- MSC.ADAMS, WorkBench,

Syllabus

- class 1 (C1)
 - Overview on Virtual Prototyping: Finite Element Analysis (FEA) and Multibody Simulation (MBS)
 - FEA (Ansys/Workbench)
- class 2 (C2)
 - Anthropomorphic Arm Modelling (FEA+MBS: Ansys/Workbench)
- class 3 (C3)
 - MBS + FEA (MSC.ADAMS + MSC.Nastran)
- class 4 (C4)

- Anthropomorphic Arm Modelling: MBS+ FEM + Control (MSC.ADAMS + MSC.NASTRAN + MatLab)
- class 5 (C5)
 - Anthropomorphic Arm Modelling: MBS + FEM + Control + Optimisation (MSC.ADAMS + MSC.NASTRAN + MatLab + ModeFRONTIER)
- class 6 (C6)
 - Final Project Assignment

Final exam

1. the minimum mark to pass the Project Assignment is 75%;
2. the Project Assignment is due 4 weeks after they are assigned and should be done in a neat and orderly fashion on PowerPoint presentation following the template (provided with the Project Theme). Late submission will not be accepted;
3. during whole course and assignment the lectures will be available anytime.

Prerequisites

Basic knowledge of classical physics and programming.

Reading List

- Klaus-Jurgen Bathe, Finite Element Procedures, Prentice-Hall of India, 2009
- Robert D. Cook, David S. Malkus, Michael E. Plecha & Robert J. Witt, "Concepts and Applications of Finite Element Analysis", 4th Edition, John Wiley & Sons, 2001 (ISBN: 0 471 35605 0)
- Rajiv Rampalli, Gabriele Ferrarotti & Michael Hoffmann, Why Do Multi-Body System Simulation?, NAFEMS Limited, 2011
- R.J.Del Vecchio, Design of Experiments, Hanser Understanding Books, 19971.

Venue

Istituto Italiano di Tecnologia, Via Morego 30 (Bolzaneto), Genova

Course dates

May-June

Remarks

Weekly homework will be assigned at the end of each lecture with an estimated average workload of 1 hours per week. Nevertheless the Project Assignment has an estimated average workload of 1-2 days.

1. the minimum attendance is 4 out 5 classrooms (the Project Assignment is not mandatory);
2. the Project Assignment should be pass according to the policy.

Applied Mechanics to Legged Robots

Course at a Glance

The course aims at giving to the Ph.D. candidates' theoretical and practical knowledge on modelling, design, and development of legged robots. Nowadays, biped, quadruped, hexapod or octopod robots are quickly becoming an important part of the mobile mechanisms. Moreover, robots have left the labs and they are entering in our human environments (e.g., ASIMO by HONDA, Atlas by Boston Dynamics, Walkman, HyQ, etc.), helping people, dealing with hazardous materials, exploring uneven terrain and dangerous environment. Bio-inspiration in robotics is a used approach to design animal-like and human-like robots. In this contest, legged locomotion is an important field which should be explored not only by control, but also by mechanical design point of view (e.g. using soft materials, flexible links, couple tolerances, joint inaccuracies, unconventional geometry, etc.). The objective of this course is to give theoretical and practical knowledge in order to be able to mechanical design basic legged robot prototypes.

Instructors

Ferdinando Cannella ferdinando.cannella@iit.it
Giovanni Gerardo Muscolo muscolo@dimec.unige.it

Credits: 5

Synopsis

This course presents an overview on legged robotics (in particular the 2-4 legs). Theoretical concepts and practical methods will be studied and implemented in virtual prototypes. The final goals of the course are twofold: 1) to give the basic notions on legged robotics from theoretical to practical point of view; 2) to merge the robotic knowledge in a virtual prototype. The course is divided in two parts of 8 and 7 hours oriented to validate the two goals described above. In the first part, real legged robots in commerce and literature will be studied in details with the final aims to underline critical points in mechanical design. In the second part, each Ph.D. candidate will propose a project with the final aim to realize a virtual prototype of a legged robot. The course comprises the use of CAD-CAE tools (PRO-Engineer) for geometric modelling and functional design and the selection of typical commercial mechanical components (actuators, gears, belts, brakes, joints, bearings). Other tools for Multi-Body Simulation (MBS), Finite Element Analysis (FEA) and trajectory planning (e.g.: MSC.ADAMS, ANSYS, COMSOL, MATLAB/SIMULINK) will be used.

Tools used:

Hardware

- Robots available (to be confirmed by the Instructor).

Software

- MATLAB/SIMULINK; OPENSIM;
- PROENGINEER;
- MSC.ADAMS; COMSOL; ANSYS;

Syllabus

- Class 1 (C1):
 - o Overview on Humanoid Robotics;
 - o Applied Mechanics to Humanoid Robots;
- Class 2 (C2):

- Theoretical Models of 2-4 Legged Locomotion;
- Design and Development of a 2-4 Legged Robot;
- Class 3 (C3):
 - Intermediate Test (IT) and Personal Project of a Legged Robot (PPLR);
 - Conceptual and Functional Design of the PPLR;
- Class 4 (C4):
 - Modelling of the PPLR;
- Class 5 (C5):
 - Simulation, Optimization, and Validation of the PPLR.

Final exam

There will be a final examination decided by the instructors. It will be related to the Intermediate Test (IT) and to the Personal Project of a Legged Robot (PPLR) performed by each Ph.D. Candidate.

Prerequisites

Basic Knowledge of Physics and Mathematics.

Reading List

- L. Sciavicco and B. Siciliano, Modelling and Control of Robot Manipulators, Springer, London, UK, 2nd edition, 2000.
- Vukobratović M. and Borovac B., 2004. Zero-moment point - thirty five years of its life, *International Journal of Humanoid Robotics*, 2004.
- B. Vanderborght, "Dynamic Stabilisation of the Biped Lucy Powered by Actuators with Controllable Stiffness", Star, Springer tracts in advanced robotics, 63 (2010).
- McGeer T., 1990. Passive dynamic walking, *International Journal of Robotics Research*, vol. V54 IS6, pp. 1–21.
- Raibert M., 2010. Dynamic legged robots for rough terrain, in 10th *IEEE-RAS International Conference on Humanoid Robots (Humanoids 2010)*, pp. 1–1, 2010.
- Kaneko K., Kanehiro F., Kajita S., Hirukawa H., Kawasaki T., Hirata M., Akachi K., and Isozumi T., 2004. "Humanoid robot hrp-2," *Proceedings of IEEE International Conference on Robotics and Automation (ICRA 2004)*, 2004.
- Collins S. H., Wisse M., and Ruina A., 2001. A three-dimensional passive-dynamic walking robot with two legs and knees, *International Journal of Robotics Research (IJRR)*, vol. 20(7), pp. 601–615, 2001.
- Muscolo G. G., Recchiuto C. T., Molfino R., 2015. Dynamic balance optimization in biped robots: Physical modeling, implementation and tests using an innovative formula. *Robotica 2015*, Vol. 33, n°10, pp. 2083-2099. Cambridge University Press.
- Muscolo G. G., Hashimoto K., Takanishi A., Dario P., 2013. A comparison between two force-position controllers with gravity compensation simulated on a humanoid arm, *Journal of Robotics*, Vol. 2013. 14 pages. <http://dx.doi.org/10.1155/2013/256364>. Hindawi Publishing Corporation.
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Venue

Istituto Italiano di Tecnologia

Course dates

October-November 2017

Human-Robot Interaction

Course at a Glance

The course will introduce the participants to the field of Human-Robot Interaction. It will discuss the contributions of the different disciplines involved and will illustrate the various methods adopted for the investigation of such a multidisciplinary topic.

Instructors

Alessandra Sciutti

alessandra.sciutti@iit.it

Francesco Rea

francesco.rea@iit.it

Hours and Credits

Total of 15 hours (6 classes of 2 hours each plus 1 class of 3 hours)

Synopsis

Understanding social interaction is a very challenging task. The dynamics of two agents interacting together is much more complex than just the sum of the behaviours of the two individuals. The actions, the movements and even the perceptual strategies each partner chooses are substantially modified and adapted to the cooperation. Notwithstanding its complexity, social interaction is of great interest not only for disciplines as neuroscience or psychology, but also from an engineering perspective. Indeed one of the biggest obstacles to a pervasive use of robots supporting and helping humans in their everyday chores relies on the absence of an intuitive communication between robotic devices and non-expert users. Several attempts have been made at achieving seamless interaction, even with positive outcomes in the context of the small manufacturing industries (e.g., the manufacturing robot Baxter). However the lack of a systematic understanding of what works and why does not allow yet for a generalization of this success in different domains. Hence, the study of Human-Robot Interaction is becoming progressively more central to foster a new generation of robots interacting naturally with their human partners.

In this course we will examine the different roles a robot could play in the context of human-robot interaction, as for instance the tutor, the collaborator, the companion or the tool of investigation. We will discuss the relevance of robot perceptual, motor and cognitive abilities for natural human-robot interaction and the good features and limitations of the currently available platforms. Furthermore the course will present the different methods adopted to investigate and evaluate the interaction between humans and robots.

Syllabus

- **Taxonomy and Open Challenges for HRI.**
- **The importance of Robot Shape, Motion and Cognition.**
- **Metrics and Experimental Design.**
- **Models of Robot Perception in HRI**
- **Models of Robot Action in HRI**
- **Attention System**

Final exam

There will be a final examination decided by the instructors.

Prerequisites

None

Reading List

There is no single text on HRI, but readings will be assigned for each class

Venue

IIT, Via Morego 30, 16163 Genova (GE)

Course dates

October-November 2017

Machine Learning Crash Course

Instructors

Lorenzo Rosasco

Lorenzo.rosasco@unige.it

Hours and Credits

Total of 24h

8 Credits

Synopsis

This course provides an introduction to the fundamental methods at the core of modern Machine Learning. It covers theoretical foundations as well as essential algorithms. Classes on theoretical and algorithmic aspects are complemented by practical lab sessions.

Tools used:

Hardware

Laptop with Matlab (optional)

Software

Matlab

Syllabus

[Local Methods and Model Selection](#)

[Laboratory - Local Methods for Classification](#)

[Local Methods and Model Selection](#)

[Laboratory - Local Methods for Classification](#)

[Regularization Networks I: Linear Models](#)

[Dimensionality Reduction and PCA](#)

[Variable Selection and Sparsity](#)

[Laboratory - PCA and Sparsity](#)

[Clustering](#)

[Applications of Machine Learning](#)

Talks by industrial partners

Final exam

There will be a final examination decided by the instructors.

Prerequisites

Bare fundamentals in Calculus and Linear Algebra. The rest of the mathematical tools needed for the course will be covered in class. This introductory course is suitable for undergraduate/graduate students, as well as professionals.

Reading List

References

- L. Rosasco. [Introductory Machine Learning Notes](#).

Further readings

- T. Poggio and S. Smale. [The Mathematics of Learning: Dealing with Data](#). Notices of the AMS, 2003
- [Pedro Domingos](#). **A few useful things to know about machine learning**. Communications of the ACM [CACM Homepage archive](#). Volume 55 Issue 10, October 2012 Pages 78-87.

- T. Hastie, R. Tibshirani, and J. Friedman. **The Elements of Statistical Learning: Prediction, Inference and Data Mining**. Second Edition, Springer Verlag, 2009 (available for free from the author's website).

Useful Links

- MIT 9.520: Statistical Learning Theory and Applications, Fall 2013 (<http://www.mit.edu/~9.520/>).
- Stanford CS229 Machine Learning Autumn 2013 (<http://cs229.stanford.edu>). See also the *Coursera* version (<https://www.coursera.org/course/ml>).

Venue

[Department of Informatics Bioengineering Robotics and Systems Engineering \(DIBRIS\)](#)

Università degli Studi di Genova - Dipartimento di Informatica, Bioingegneria, Robotica e Ingegneria dei Sistemi Via Dodecaneso, 35, 16146 Genova, Italy.
<https://goo.gl/maps/2ydsnFJcC1J2>

Accommodations:

http://lcs.mit.edu/courses/common_data/hotels.pdf

Course dates

26 – 30 June 2017

Physiology of Perceptual Systems

Course at a Glance

The course Neurophysiology of the sensory systems and multisensory integration will review the main functional characteristics and the anatomical and physiological bases of the visual and motor systems. The course will also cover recent advances in selected topics. See the synopsis and the syllabus for more details. The course is organized by the U-VIP group at the Italian Institute of Technology.

Instructors

Monica Gori -- Istituto Italiano di Tecnologia (IIT) , monica.gori@iit.it

Hours and Credits

8 hours 3 credits

Synopsis

From birth, we interact with the world through our senses and movements. How the brain process and transform sensory signals into perceptions and in turn organise the motor output is a major research question in Experimental Psychology and Neuroscience. The goal of the course is to present the perceptual and motor systems from the anatomical, physiological and functional points of view. A particular focus will be on how physical stimuli are transduced into sensory signals by our peripheral sensory apparatus, as well as how the motor hierarchy organize complex behavior. In the last part of the course, these topics will be described in relation with cross-sensory interaction and multisensory integration in the adult and the developing brain.

Syllabus

- class 1 (C1) Visual system I.
- class 2 (C2) Visual system II.
- class 3 (C3) Sensory and motor development.
- class 4 (C4) Multisensory Integration and Cross-Sensory Interactions.

Final exam

There will be a final examination decided by the instructors.

Prerequisites

None

Reading List

- Kandel, Eric R.; Schwartz, James Harris; Jessell, Thomas M. (2000) [1981], Principles of Neural Science (Fourth ed.), New York: McGraw-Hill.
- Sensation & Perception, by Jeremy M. Wolfe, Rachel S. Herz, Roberta L. Klatzky, Linda M. Bartoshuk

Venue

The course will be held at IIT (Istituto Italiano di Tecnologia), Via Morego 30, 16163 Genova

Course dates

The course will be held on September, 2017

Psychophysics Methods

Course at a Glance

The course Psychophysics Methods will briefly review the principal methods used in psychophysics to measure sensory thresholds and perceptions in general. See the synopsis and the syllabus for more details. The course is organized by the U-VIP group at the Italian Institute of Technology.

Instructors

Monica Gori -- Istituto Italiano di Tecnologia (IIT) , monica.gori@iit.it

Hours and Credits

total of 8 hours 3 credits

Synopsis

Psychophysics investigates the relationship between stimuli in the physical domain and sensations or perceptions in the psychological domain. It provides a corpus of well-established methods to study and formulate models of perception. The course will start with a review of the history of psychophysics and of the principal results obtained in this field. Then, the course will present some psychophysical concepts (e.g., the concepts of sensory threshold and psychological scale) and describe classic and modern psychophysical methods to measure them. The students will have the opportunity to make simple psychophysical experiments in class to test their understanding of the methods.

Tools used:

Hardware

Laptop

Syllabus

- class 1 (C1) History of psychophysics and concept of threshold.
- class 2 (C2) Methods of threshold measurement
- class 3 (C3) The measurement of Sensory Attributes and Discrimination Scales.
- class 4 (C4) Laboratory

Final exam

There will be a final examination decided by the instructors.

Prerequisites

none

Reading List

- Psychophysics the fundamentals, George A. Gescheider

Venue

The course will be held at IIT (Istituto Italiano di Tecnologia), Via Morego 30, 16163

Course dates

The course will be held on June, 2017

Introduction to nonlinear control theory

Course at a Glance

The course aims at introducing methods for analysis and control of nonlinear systems. Particular attention is paid to time domain analysis techniques, such as Lyapunov stability and feedback linearization. Applications to robotic manipulators are also presented. The course is co-organized by the Robotics, Brain and Cognitive Science Department, Istituto Italiano di Tecnologia (IIT).

Instructors

Daniele Pucci (RBCS) daniele.pucci@iit.it,

Credits:

5

Synopsis

Over the last three decades, nonlinear control techniques have experienced a tremendous boost, which led to several applications in aviation, robotics, chemistry, and industrial processes. In fact, advances in modeling and computer-aided design systems allow us to simulate complex and highly nonlinear processes, the robust control of which may require more than simple linear controllers. This course introduces control techniques for nonlinear ordinary differential equations powered by control variables. Emphasis is given on cases where linear methods are not sufficient for ensuring large domains of stability and robustness. Applications to robotic manipulators is also presented with simulations performed in the MATLAB environment, and on the real platform iCub.

Syllabus

Duration of the course: 12 -14 hours

- From linear to nonlinear: recap of linear systems and peculiar phenomena in nonlinear systems.
- Fundamental properties: existence and uniqueness of solutions to differential equations. Fundamentals of stability. Interconnected systems.
- Lyapunov stability 1: autonomous systems. Definitions of Lyapunov functions, la Salle principle. Stability of nonlinear systems from linearization.
- Lyapunov stability 2: nonautonomous systems. Linear time-varying systems. Converse theorem. Barbalat lemma and its applications.
- Feedback control: stabilization via linearization, integral control, and gain scheduling.
- Feedback linearization: theory and applications to robotic manipulators.
- Nonlinear design tools: backstepping, adaptive control with applications to robotic manipulators.
- Advanced stability analysis: center manifold theorem, region of attraction, stability of periodic solutions.

There will be a final examination decided by the instructors.

Prerequisites

Multivariable calculus, linear differential equations, control of linear systems.

Reading List

- 1) Nonlinear systems, H. K. Khalil
- 2) A mathematical introduction to robotic manipulation, R.M. Murray, A. Li, S. S. Sastry
- 3) Nonlinear control systems, A. Isidori

Venue

Istituto Italiano di Tecnologia, Via Morego 30, Bolzaneto, Genova

Course dates

December 2017

Data manipulation and reproducible research in R.

Course at a Glance

R is more than a statistical software. R can be used at all stages of your research, to process the data collected during the experiment, to make graphics, to analyse them and to write reports and manuscripts (including nice tables, equations, etc.). With a bit of organization, you can perform all these steps within R in an automated manner. In this course, you will learn a work flow to perform all these steps.

Instructors

Gabriel Baud-Bovy

gabriel.baud-bovy@iit.it

Hours and Credits

12 hours

4 CF

Synopsis

This course aims at giving to the student a methodology to analyze experimental results, from how to organize data to writing reports. It includes:

- an overview of R
- an introduction to reproducible research with R (knitr, rmarkdown)
- an introduction to several packages for data manipulation (e.g., reshape2, dplyr, tidyr) and graphics (lattice; ggplot2)
- examples of statistical analysis with R

During this course, the student will have to analyze his own data and is expected to read before each course the material that will be made available on this page.

Tools used:

Hardware

- Your laptop

Software

- R (<https://cran.r-project.org/>)

Syllabus

Class 1: Case study, Reproducible research

Class 2: R fundamental (R objects, data types, programming)

Class 3: Exploratory data analysis and graphical methods in R

Class 4: Basic statistics

Final exam

The final exam will consist in the evaluation of a report demonstrating familiarity with the concepts and methods presented in the course.

Prerequisites

- The course assumes some familiarity with programming concepts and data structures (MATLAB, C/C++, Java or any other programming language). Contact the instructor if you have never programmed anything.
- Install R on your laptop.
- Bring a data set that you want to analyze.

Reading List

- R Core Development Team “An introduction to R”.

Venue

IIT-Morego

Course dates

- march 20– Sala Montalcini 10-13
- march 27 – Sala Volta 14-17
- april 3 – Sala Volta 14-17
- aprile 10 – Sala Montalcini 10-13

References

- Hadley Wickham. Ggplot2: Elegant Graphics for Data Analysis
- tidy: <http://vita.had.co.nz/papers/tidy-data.html>
- Baud-Bovy (2014) Notes on reproducible research with R

Remarks

Software:

- The R Project website: <http://cran.r-project.org/> (to download R, R packages knitr and R documentation)
- pandoc: <http://johnmacfarlane.net/pandoc/index.html>
- Notepad++: <http://notepad-plus-plus.org/>
- NppToR: <http://sourceforge.net/projects/npptor/>
- MikeTex: <http://miktex.org/>
- R studio: see <http://www.rstudio.com/>
- .knitr website: <http://yihui.name/knitr/>