PhD Courses offered (2022-2023)

Summary

Outline of Courses

The offered courses can be roughly grouped into three distinct classes:

Crossover courses oriented to scientific methodology, writing, results exploitation, and intellectual property protection.

Foundation courses oriented to basic disciplines of robotics and bioengineering

Advanced courses oriented to specific doctorate curricula.

In the following, the courses offered in each class by the doctorate are listed along the instructors and the number of credits.

Crossover Courses

Mandatory Courses (25 Credits)

Theatrical techniques for scientific presentation[1]	5
Ethics and Bioethics in Bioengineering and Robotics[1]	5
Paper Writing[1]	5
Grant writing[2]	5
Bioengeneering, A.I. and Robotics: applicable law, liability, contract and data protection.	3
An Introduction to Open Science and Research Data Management	3

Basic and Foundation Courses

Introduction to Computer Programming for Researchers[3]	2
Data acquisition and data analysis methods	2

Programming

C++ programming techniques	6
Robot programming with ROS	5
Modern C++	5

Mechanical Design

Mechanical Drawing Fundamentals (BASIC)	2
Computer aided design	5

[1] Recommended for 1st year students
[2] Recommended for 2nd and 3rd year students
[3] For non-engineers

Modelling and Computational Methods

An introduction to spatial (6D) vectors and their use in robot dynamics	4
Computational Robot Dynamics	5
Interaction in Virtual and Augmented reality	6
Computational models of visual perception	4
Perceptual Systems	4
Electronics and Circuits (level 1)	3
Electronics and Circuits (level 2)	3
Electronics and Circuits (level 3)	3
Electronics and Circuits (level 4)	3

Advanced Courses

Cognitive Robotics for Human-Robot Interaction	6
Introduction to physical Human-Robot Interaction	5
Optimization-based trajectory planning for legged robots	4

Robotic technologies for sensorimotor rehabilitation	5
Robotic Virtual Prototyping Design	6
Trustworthy AI: Learning from Data with Safety, Fairness, Privacy, and Interpretability Requirements	5

Theatrical techniques for scientific presentation

Scientific Disciplinary Sector: ING-INF/05

Number of hours: 12

Credits: 4

AIMS AND CONTENT

Learning Outcomes (short)

Upon successful completion of this course, students will be able to successfully prepare a scientific presentation for a specific audience, and to deliver it to the public by using their voice, their body and the space around them in the most efficient way as possible.

Syllabus/Content

Topics covered will include:

- How to prepare a presentation by taking into account the scientific context and the public;
- Structuring the presentation: the importance of the beginning and the end;
- Scientific journals and conferences;
- Theatrical techniques to use the space;
- Theatrical techniques to use the body;
- Theatrical techniques to use the voice.

Ethics and Bioethics in Bioengineering and Robotics

Scientific Disciplinary Sector: MED02/MED43/IUS20/M-FIL03

Number of hours: 15

Credits: 5

AIMS AND CONTENT

Learning Outcomes (short)

Upon successful completion of this course, students will be able to

- explain some of the key ethical issues in bioengineering and robotics
- identify ethically problematic facets of a project
- apply an ethical decision-making framework to a scenario in order to determine an ethically appropriate course of action.

Learning Outcomes (further info)

Can ethical considerations be incorporated into the design of novel artifacts? What duties and obligations do researchers have towards research participants? How can we develop models of human-robot interaction that preserve human values?

Increasingly, researchers and professionals in the fields of bioengineering and robotics are faced with ethical questions like these. The goal of this course is therefore twofold: first, to develop PhD students' sensitivity to the ethical issues that arise in research and professional practice, and, second, to provide them with knowledge and tools that will help them navigate ethically complex scenarios and reach ethically appropriate decisions.

Syllabus/Content

Topics covered will include:

- Ethics and bioethics: concepts and frameworks
- Ethical decision-making
- The requirements of ethical research
- Research protocols and ethical review
- Informed consent
- Personal data and privacy
- Value Sensitive Design

The reading list will be provided after the first session.

Grant Writing

Scientific Disciplinary Sector: ING-INF/05

Number of hours: 12 hours

Credits: 5 CFU

AIMS AND CONTENT

Learning Outcomes (short)

The course will present and discuss guidelines on how to design a research grant proposal and on the coordination of a research grant, with a special focus on European Horizon 2020 and the upcoming Horizon Europe Franework Programmes.

Learning Outcomes (further info)

A particular focus will be on ICT, Creative Europe, FET, ERC. Use cases of successful projects coordinated by the teacher will be studied and analyzed. A short simulation of the development process of a draft research proposal will conclude the course.

Syllabus/Content

European research grants, EU Horizon 2020, Horizon Europe, ICT, FET, ERC.

Bioengeneering, A.I. and Robotics: applicable law, liability, contract and data protection.

Scientific Disciplinary Sector: IUS/01 IUS/02 IUS/05 IUS/17

Number of hours: 6

Credits: 3

AIMS AND CONTENT

Learning Outcomes (short)

At the end of the course the students will be able to:

- - get aquainted with the basic legal issues linked to the new technologies, A.I. and robotics areas
- - enhance the knowledge of the European and Italian Law liability rules in relation to the producer, the designer and the seller.
- - learn when, why, how to make a project in compliance with applicable law.
- - be aware of the legal effects in order to make a decision.
- - know data protection rules

Learning Outcomes (further info)

1. *How can we develop models of human-robot interaction that respect the law principles? How can set forth the liability for damages? Who does bear the relevant risks? Which kind of contracts can we provide?*

   Researchers and professionals in bioengineering, A.I. and robotics areas deal with legal questions like these. The course aims to: develop PhD students' ability to identify legal issues that could arise in research and professional practice and provide them with the knowledge and tools that will sort out legal problems in the complex scenarios and reach appropriate decisions.

Syllabus/Content

1. Topics covered will include:
   - Basic concepts of European and National law (U.E. directives, resolutions, italian laws)
   - Knowledge of legal issues, expecially on liability
   - Product Liability and Consumer Protection
   - Data Protection (GDPR)
   - General Principles of Contract Law and Intellectual Property Law
   - Case studies

     The reading list will be provided after the first session.

An Introduction to Open Science and Research Data Management

Scientific Disciplinary Sector: ING/INF-06

Number of hours: 6

Credits: 3

AIMS AND CONTENT

Learning Outcomes

Training Course for PhD Students, composed of four modules. It aims to introduce early-career researchers to scholarly communication and to the principles of Open Science (Open Access to Publications, Open Data, Open Licenses) and Research Data Management. At the end of the course students will have a better understanding of the available research e-infrastructures, tools, and services for Open Access Publication, Research Data Management and FAIR Data. Students will also learn the importance of open science in research, especially to improve science reproducibility and increase research integrity. They will learn how to make research data FAIR, as required by many funders, including the European Commission. Finally, they will have the chance to practice on common tools for Research Data Management, like DMPOnline and Zenodo.

Contents

<u>Module 1:</u>

Setting the context: why open science? (V. Pasquale, A. M. Pastorini) – 15 minutes

Open science: a definition; benefits of open science: for researchers and for the scientific system and society as a whole.

Short intro to the contents of the course.

Scholarly communication (A. M. Pastorini) – 45 minutes

What is scholarly communication; the publication cycle and type of publications; peer-review process; bibliometrics (impact factor, h-index, other indicators, bibliometrics limits); citation databases; avoid plagiarism; literature search engines and reference managers.

The management of rights in scholarly communication (A. M. Pastorini) – 30 minutes

Intellectual property: trademarks and patents; author's rights and copyright (Italian and European contexts); fair use vs exceptions and limitations to rights; editorial policies: contract and license; open access as an economic model; open licenses for sharing contents and data

<u>Module 2:</u>

Open access in scholarly communication (A. M. Pastorini) – 45 minutes

Overview on open access; open digital repositories and institutional archives; open access journals and bibliometrics; the different business models of open access; cOAlitionS and PlanS; OA policies and regulations (with specific reference to Unige and IIT context).

Author's rights and PhD Thesis (A. M. Pastorini) – 45 minutes

Author's rights and PhD Thesis; regulation about PhD Thesis; the submissions of PhD Thesis in the institutional repository (IRIS UniGe); information and support: the OS UniGe website www.openscience.unige.it; open science & RDM support in IIT (*V. Pasquale*).

Module 3

What is Research Data Management? (V. Pasquale) – 15 minutes

Research data management: a definition; Research data lifecycle: from data management planning to sharing.

The Research Data Lifecycle: Plan & fund (V. Pasquale) – 30 minutes

Funder requirements; data management planning; data ownership; basic notions of data privacy & ethics; support for DMP in IIT.

Hands-on activity: using DMPOnline for data management planning (V. Pasquale) – 45 minutes

Students will be asked to log in DMPOnline and draft a data management plan of their PhD project.

Module 4

The Research Data Lifecycle: Work with data (V. Pasquale) – 15 minutes

Secure storage & backup; tips & tricks: file formats, data organisation, filenaming conventions, version control and house-keeping; data documentation: electronic lab notebooks.

The Research Data Lifecycle: Preserve & share (V. Pasquale) – 35 minutes

FAIR data: how to make your data FAIR; data and metadata standards; digital preservation: repositories, open data licenses, persistent identifiers, how to make your research outputs (data, models, code) citable; why data sharing is important: meta-analysis & meta-reviews.

Hands-on activity: share a dataset in Zenodo (V. Pasquale) – 40 minutes

Students will be asked to log in Zenodo-sandbox and create a mock dataset.

Introduction to Computer Programming for Researchers

Scientific Disciplinary Sector: INF/01

Number of hours: 15 hours

Credits: 2 CFU

AIMS AND CONTENT

Learning Outcomes (short)

The course will take the students with no or minimal prior experience of programming through the main principles and best practices of programming. The course is intended for researchers who wish to learn the Python programming language.

Learning Outcomes (further info)

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.

Syllabus/Content

- 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

Data Acquisition and Data Analysis Methods

Scientific Disciplinary Sector: ING-INF/04 OR ING-INF/05 OR ING-INF/06

Number of hours: 15

Credits: 5

AIMS AND CONTENT

Learning Outcomes (short)

The course is aimed at students who intend to acquire knowledge to develop measurement systems and data analysis algorithms to be adopted in general applications (robotics, test benches, sensor data acquisition). This course presents an overview about data acquisition and data analysis methods. In a first part methods used in modern data acquisition systems will be described with a special focus on hardware and electronics. The second part will focus on the data analysis side of a measurement process. The aim is to learn how to get the information hidden inside the data, even in presence of noise, using statistical and computing methods.

Learning Outcomes (further info)

When successfully accomplished the course the student will have a comprehensive view on how to set up a data acquisition system: the course will give to the student the capabilities to choose the most appropriate hardware depending from the quantity to be measured and the application. Part of the course will be dedicated to learn how to properly design a DAQ system and all the related problematic (sampling rate, noise, amplification, etc.). An overview about Electronics (including microcontrollers, FPGA, amplifiers and analogue electronics, commonly used BUS and sensors) will be discussed. Moreover the course will give an overview of the data analysis process: starting from the raw data, acquired using the instruments presented in the first part of the course, and ending with the physical information. After a brief review about measurements and uncertainty, an overview of random variables, outcomes of experiments and propagation of uncertainty will be presented. Then useful statistical methods to present and treat the data will be discussed. Finally some real examples of data analysis using MATLAB® will be shown.

Syllabus/Content

9 hours,

- Data acquisition methods
- Sensors and measurements methods
- Introduction to Electronics 1 (Amplifiers, Filters, S/N ratio, ADC)
- Introduction to Electronics 2 (Real Time systems and Data Acquisition)
- Example and applications

6 hours

- Dealing with uncertainties (1h)
- Introduction to Statistical methods (1h)

- Data analysis using MATLAB® (4h)
    - Curve fitting and parameters identification
    - Periodicity analysis and pre-processing tools

C++ programming techniques

Scientific Disciplinary Sector: INF/01

Number of hours: 18 hours

Credits: 6 CFU

AIMS AND CONTENT

Learning Outcomes (short)

This course introduces the specificities of C++ object oriented programming language and focuses on the use of C++ for the implementation of object-oriented software modules. In particular, programming techniques to tackle the issues of memory management, robustness and efficiency are considered.

Learning Outcomes (further info)

Syllabus/Content

- 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.

Robot programming with ROS

Scientific Disciplinary Sector: ING-INF/05

Number of hours: 15 hours

Credits: 5 CFU

AIMS AND CONTENT

Learning Outcomes (short)

- Learning and understanding the ROS communication architecture.
- Understanding the ROS2 basic concepts and how to integrate ROS2 with ROS1 systems
- Learning how to implement ROS-based cloud robotics applications
- Using native ROS code on Android

Learning Outcomes (further info)

ROS is a robotic middleware that offers a collection of packages for commonly used functionality, low-level control, hardware abstraction, and message passing. Given all these aspects, it has become a standard in robotics. The course will explore its most relevant functionalities, with the help of different examples, analyzing how the ROS framework may help in solving common problems in robotics. Please notice that the course will not describe in detail the ROS framework, but it will give some general operative instructions (classes I and II), and it will then deal with some specific aspects (classes III-V): the integration of ROS systems with ROS2 systems, the development of ROS-based cloud robotics applications, and the possibility of using native ROS code on Android. For this reason, the course may be useful both for students that are already proficient with ROS, which may review some general aspects and possibly learn some new concepts, and for students who have never used ROS, which will receive some insights about ROS (that may be possibly individually deepen) and some of its features. The course will foresee the usage of some commonly used robotic simulators, such as Gazebo and VREP, giving the possibility of practically testing the ROS features. During the course, a Docker image with ROS and ROS2 already installed will be given to students.

Syllabus/Content

- Class I (C1) (3 hours) - Introduction to ROS Topics, Services and Nodes. Class examples -
- Class II (C2) (3 hours) - Software representation of a Robot and robotic.simulations with Gazebo. Class examples. Guided exercise
- Class III (C3) (3hours) – ROS2 Topics, Services and Nodes and ROSI bridge. Class examples. Assignment I
- Class IV (C4) (3 hours) –Cloud Robotics Frameworks and ROS. Class examples. Guided exercise
- Class V (C5) (3 hours) – RosJava and ROS for android. Class examples. Assignment II.

Modern C++

Scientific Disciplinary Sector: ING-INF/05 / ING-INF/06

Number of hours: 15

Credits: 5

AIMS AND CONTENT

Learning Outcomes (short)

The students will learn the new syntax and philosophy of Modern C++ (releases C++11, -14, -17).

Learning Outcomes (further info)

Left intentionally empty.

Syllabus/Content

Each of the following modules will be 2.5 hours each

1. Introduction: presentation of the course, refresh of C++98.
2. The basics: nullptr, auto, type aliases, initializer list, uniform initialization
3. The basics: range based loops, constexpr, scoped enums, override and final.
4. Advanced topics: move semantics, smart pointers
5. Advanced topics: lambda functions, STL containers, algorithms
6. Advanced topics: concurrency

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Mechanical Drawing Fundamentals

Scientific Disciplinary Sector: ING-IND/15

Number of hours: 18 hours

Credits: 2 CFU

AIMS AND CONTENT

Learning Outcomes (short)

This course provides an introduction to Mechanical Technical Drawing with mention to manufacturing techniques. The aim of the course is to give a base knowledge in understanding and preparing mechanical technical drawings, so there is no need of prior background of mechanical drawing.

Learning Outcomes (further info)

Mechanical drawing is the main way to communicate design need to technicians, workshops, suppliers. A base knowledge of rules and methods helps the researcher, even if not directly engaged in mechanical design, to better contribute to interdisciplinary team working when involved in the design of experimental setups, scientific devices, and the writing/understanding of technical specifications.

Syllabus/Content

- **Introduction** (projection methods and orthogonal projections theory)
- **Technical Drawing Rules** (lines rules, sections, dimensioning)
- **Drawing for manufacturing** (proper dimensioning and prescriptions according to production method)
- **Tolerances and surface finish** (dimensional and geometrical tolerances, roughness)
- **Representation of main removable and non-removable connections** (welds, threads)

Computer Aided Design

Scientific Disciplinary Sector: ING-IND/15

Number of hours: 12 hours

Credits: 5 CFU

AIMS AND CONTENT

Learning Outcomes (short)

The aim of the course is to gain and apply knowledge of advanced CAD concepts and techniques by using high-end CAD systems (i.e. *PTC Creo*).

Learning Outcomes (further info)

The course deals with the main CAD modeling techniques to develop the virtual model (DMU) of complex industrial products. The main topics are: 3D parametric and explicit modeling, feature modeling, surface modeling, geometric drawings, assembly modelling, parametric expressions and curves. Tolerances. Manufacturing drawings. Sheet Metal Technology. Basic stress and dynamic analysis.

Syllabus/Content

Main geometry representation schemes: 2D and 3D mathematical models (Vertex, Line, Surface, Solid, Assembly), main models for geometry exchange (IGS, STP, STL).

Solid modeling CSG and B-Rep: main features of 3D CAD modelers, sketch-based modelers, parametric modeling, the concept of history-based modeling, feature-based modeling.

Assembly-based modeling: top-down setting bottom-up; use of part skeleton and assembly; structuring of an assembly; flat and/or sub-assemblies and implications in project management.

Modeling aimed at the product concept: continuous curvature parametric curves, double curvature surfaces (free-form) based on curves, modeling of surfaces from edge curves, modeling of path-based surfaces and the concept of sweeps.

Direct modeling: management of the history-free models

Geometry preparation techniques for structural simulations. Basic simulations with integrated tools (*Creo Mechanisms and Creo Simulate*).

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

Scientific Disciplinary Sector: ING-INF/04

Number of hours: 10

Credits: 4

AIMS AND CONTENT

Learning Outcomes (short)

The course provides an introduction to spatial vector algebra, which is a tool that simplifies the task of solving problems in rigid-body dynamics by reducing the quantity of algebra needed to describe and solve a problem, and reducing the amount of computer code needed to calculate the answer.

Learning Outcomes (further info)

Spatial vectors combine the linear and angular aspects of rigid-body motion, so that a single spatial vector can provide a complete description of a rigid-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.

Syllabus/Content

- motion and force
- Plucker coordinates
- differentiation and acceleration
- equation of motion
- motion constraints

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 (vector spaces and subspaces, bases, coordinates, linear independence, range and null spaces of a matrix, etc.)

Computational Robot Dynamics

Scientific Disciplinary Sector: ING-INF/04

Number of hours: 12

Credits: 5

AIMS AND CONTENT

Learning Outcomes (short)

The course covers the fundamentals of computational robot dynamics: dynamic models of robots; inverse, forward and hybrid dynamics; and the process of dynamics simulation.

Learning Outcomes (further info)

Most dynamics simulation today is performed by specialized 'black-box' simulators that hide the details from the user. Unfortunately, many of these simulators are inaccurate, buggy, or suffer from a variety of limitations. This course provides students with the necessary knowledge to become competent users (and producers) of dynamics software. Topics range from equations of motion through to model-based dynamics algorithms and techniques for accurate and reliable simulation.

Syllabus/Content

- basic equations of motion
- inverse dynamics, and the idea of a recursive algorithm
- efficient implementation of spatial vector arithmetic
- forward and hybrid dynamics
- dynamic models of robots
- the integration process

Prerequisites: It is desirable, but not necessary, that students take the preceding course on spatial vectors. Students who have not taken this course should nevertheless have a basic knowledge of classical Newtonian dynamics (i.e., dynamics using 3D vectors).

Interaction in Virtual and Augmented Reality

Scientific Disciplinary Sector: INF/01

Number of hours: 20 hours

Credits: 6 CFU

AIMS AND CONTENT

Learning Outcomes (short)

The course will present the fundamentals of the design, implementation and assessment of virtual (VR) and augmented reality (AR) environments, and the techniques to interact within such environments. Particular attention will be paid to the perceptual issues and to the ecological interaction in VR and AR.

Learning Outcomes (further info)

Syllabus/Content

- Introduction to VR and AR: techniques and devices
- Immersivity, presence, quality of experience, and adverse symptoms: study and evaluation.
- Interaction in VR and AR: devices and software solutions. Techniques for ecological interaction.
- Perceptual issues when acting in virtual and augmented reality.
- Examples and case studies

Interaction in Virtual and Augmented Reality

Scientific Disciplinary Sector: INF/01

Number of hours: 20 hours

Credits: 6 CFU

AIMS AND CONTENT

Learning Outcomes (short)

The course will present the fundamentals of the design, implementation and assessment of virtual (VR) and augmented reality (AR) environments, and the techniques to interact within such environments. Particular attention will be paid to the perceptual issues and to the ecological interaction in VR and AR.

Learning Outcomes (further info)

Syllabus/Content

- Introduction to VR and AR: techniques and devices
- Immersivity, presence, quality of experience, and adverse symptoms: study and evaluation.
- Interaction in VR and AR: devices and software solutions. Techniques for ecological interaction.
- Perceptual issues when acting in virtual and augmented reality.
- Examples and case studies

Computational models of visual perception

Scientific Disciplinary Sector: INF/01

Number of hours: 12 hours

Credits: 4 CFU

AIMS AND CONTENT

Learning Outcomes (short)

This course introduces paradigms and methods that allow students to develop computational models of visual perception, which are based on hierarchical networks of interacting neural units, mimicking biological processing stages.

Learning Outcomes (further info)

Syllabus/Content

- Introduction to visual perception and to the cortical dorsal and ventral streams for action and recognition tasks.
- Hierarchical networks of functional neural units. Computational models of the visual features estimation for action and recognition. Comparison among computational models and computer vision algorithms. Benchmark Datasets. How to use computational models to improve virtual and augmented reality systems to allow natural perception and interaction.
- Case studies: models and algorithms of the literature.

Perceptual systems

Scientific Disciplinary Sector: M-PSI/01

Number of hours: 12

Credits: 4

AIMS AND CONTENT

Learning Outcomes (short)

Students will learn how the functioning of the main sensory systems, i.e. vision, audition, touch, small and taste. Moreover, it will be explain the process of multisensory integration and cross-modal interaction.

Learning Outcomes (further info)

From birth, we interact with the world through our senses. How the brain process and transform sensory signals into perceptual outputs is one of the main questions in the field of experimental psychology. The goal of the course is to present the perceptual 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 in a hierarchy organize complex behaviour. 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/Content

Class 1 (3 hours): Visual system I.
Class 2 (3 hours): Auditory and tactile systems.
Class 3 (3 hours): Multisensory integration and development of sensory systems.
Class 4 (2 hours): Olfactory and gustatory systems and cross-modal interaction.
Class 4 (1 hours): Final Exam.

Electronics and Circuits

Unit code: (filled by Unige administrative office)

Scientific Disciplinary Sector: ING/INF-01

Number of hours: 48 (divided in 4 Levels of 12 hours each)

Credits: 3 each level

AIMS AND CONTENT

Learning Outcomes (short)

Level 1: analog and digital electronics

Level 2: mixed signals and data conversion

Level 3: design of electronic modules

Level 4: more advanced design techniques

Learning Outcomes (further info)

Level 1: learning basic Operational Amplifier circuit design and practices; learning digital electronics basics.

Level 2: understanding Analog-to-Digital and Digital-to-Analog conversion and being able to write the specifications of an analog system for signal conditioning and of a mixed-signal system (signal conditioning, data acquisition, filtering) to provide to a thirdy-part designer or to select an off-the-shelf solution available on the market

Level 3: more electronic components; schematic circuit design of “standard modules” to be used as building-blocks in more complex or custom systems

Level 4: more advanced technical issues (e.g. circuit layout dos and don’ts), circuit design best practices, CAD tools.

Syllabus/Content

Level 1: students will learn the Operational Amplifier and will be able to go through a typical Datasheet, understanding the various features and characteristic curves. In this module they will practice with basic circuits while learning how to optimize the design in terms of requested features (e.g. noise, stability, etc.).
In the second part students will go through the basics of digital design, confining the activities on typical digital building blocks useful for the following Level 1 module.

Level 2: students will mix the acquired concepts into the A/D and D/A technologies, learning how to select the appropriate converter for a given application especially in terms of resolution and speed. They will afford a real-case situation where an input analog signal must be pre-processed and filtered before the converter stage.

Level 3: this module will offer some details about other components useful to afford the design of more complex systems. Based on the knowledge of the two preceding modules, students will be ready to design circuits intended as more or less standard building blocks for complex applications, determining the design parameters and selecting the best options vs. the case study. Examples of real-life schematics will offer a good dictionary of solutions.

Level 4: with the background of the preceding modules, it is time to go the insights of the electronic design with a series of good and bad circuits to analyze and discuss, exploiting what learned till now and being ready to understand what are the best practices of “the art of electronics”. Students will also approach a CAD program to design circuits and the corresponding Printed Circuit Boards.

Cognitive Robotics for Human-Robot Interaction

Scientific Disciplinary Sector:

Number of hours: 18 hours

Credits: 6 CFU

AIMS AND CONTENT

Learning Outcomes (short)

The participants will learn the key aspects regulating the interaction between human and robots, and will have an overview of good features and limitations of currently available platforms for HRI. Students will learn how to conduct an HRI study and which metrics are appropriate to characterize the interaction.
Participants will be provided with an overview of some computer vision useful to make robots able to understand the nonverbal behaviors of the human partner (e.g. facial expressions and body movements) and other perceptual models of cognitive robotics. Further the participants will be provided with an overview on how actions can close the action-perception loop with human partners and how these models integrate in broader cognitive architectures for HRI. The survey across cognitive models of perception and action will give to the participants the opportunity to successfully design new behaviors for interacting robots.
Moreover, participants will have the chance to program the humanoid robot iCub.

Learning Outcomes (further info)

In this course the students will learn 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, and the corresponding different models of interaction. The course is aimed at providing a clear understanding of what are the good features and limitations of the robotic platforms currently available.
The students will learn how to use computer vision and machine learning techniques to endow the robot with the capability of understanding human behaviors (for instance motion and facial expressions) that are relevant in a natural human-robot interaction.
The participants will learn how to design and implement robot perceptual, motor abilities structured in a cognitive framework for natural human-robot interaction, and will have the chance to learn how to program the humanoid robot iCub.

Syllabus/Content

Taxonomy and Open Challenges for HRI

The importance of Robot Shape, Motion and Cognition

Metrics and Experimental Design

Computer Vision for HRI

Models of Robot Perception and Action in HRI

Software Development of perception and action models in HRI

Introduction to physical Human-Robot Interaction

Scientific Disciplinary Sector: ING-INF/06

Number of hours: 12 hours

Credits: 5 CFUs

AIMS AND CONTENT

Learning Outcomes (short)

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.

Learning Outcomes (further info)

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/Content

- 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
- Laboratory

Optimization-based trajectory planning for legged robots

Scientific Disciplinary Sector: ING-INF/05

Number of hours: 14

Credits: 4

AIMS AND CONTENT

Learning Outcomes (short)

This course will introduce modern methods for robotics movement generation based on numerical optimal control. An introduction to approximated models is also given (Linear Inverted Pendulum and Centroidal Dynamics). It will also contain hands-on exercises for real robotic applications such as walking on flat terrain.

Learning Outcomes (further info)

The student will be able to generate a locomotion trajectory for the robot via optimization and track it with the controller implemented in the previous course of “Control of legged robots”.

Syllabus/Content

Reduced Models:

D1 Introduction to Trajectory optimization, reduced models

D2. Linear Inverted pendulum: derivation of dynamics from the centroidal dynamics

D3. Linear Inverted pendulum + flywheel: incorporation of moments about com

D4. Cart-Table model

D5. 3D ZMP Model

D6. Other locomotion models: point mass model, inverted pendulum, spring-loaded inverted pendulum (Limit cycles, Poincarrè map)

D7. Single Rigid Body Centroidal Dynamics model

D8. Capture point (derivation from LIP dynamics or from orbital energy, analysis of lip dynamics, stable, unstable eigenvectors, stability analysis of COM ZMP and CP)

D9. Capture point and real robots (finite size feet, capturability regions)

Trajectory Optimization:

E1. Overview on Optimal control Problems: Single shooting / Direct collocation for CoM trajectory optimization

E2. Discretization of the LIP dynamics (forward Euler, exact discretization with matrix exponentials), assembly of the support polygon constraints

E3. Closing the loop with the whole-body controller, implementation of a real robot, from reduced models to full dynamics

E4. Idea of MPC re-planning

Lab Sessions:

L1. Trajectory optimization: CoM planning with LIP model

L2. Close the loop with the QP controller implemented in the propedeutic course "Control of legged robots" and simulate a walk for a quadruped robot

Robotic technologies for sensorimotor rehabilitation

Scientific Disciplinary Sector: ING-INF/06

Number of hours: 16 hours

Credits: 5 CFUs

AIMS AND CONTENT

Learning Outcomes (short)

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.

Learning Outcomes (further info)

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/Content

- 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
- Laboratory

Robotic Virtual Prototyping Design

Scientific Disciplinary Sector:

Number of hours: 18 hours

Credits: 6 CFU

AIMS AND CONTENT

Learning Outcomes (short)

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 behavior of physical systems: joined together permit to study the dynamics taking in account the body flexibility, the control and optimization. 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.

Learning Outcomes (further info)

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.

Syllabus/Content

- class 1 (C1)
  - Overview on Virtual Prototyping: Finite Element Analysis (FEA) and Multibody Simulation (MBS)
  - FEA (Ansys/Workbanch)
- class 2 (C2)
  - Anthropomorphic Arm Modelling (FEA+MBS: Ansys/Workbanch)
- class 3 (C3)
  - MBS + FEA (MSC.ADAMS + MSC.Nastran)
- class 4 (C4)
  - MBS + FEA + Embedded Control (MSC.ADAMS + MSC.Nastran)
- class 5 (C5)
  - Anthropomorphic Arm Modelling: MBS+ FEM + Co-Simulation Control (MSC.ADAMS + MSC.NASTRAN + MatLab)
- class 6 (C6)
  - Anthropomorphic Arm Modelling: MBS + FEM + Control + Optimisation (MSC.ADAMS + MSC.NASTRAN + MatLab + ModeFRONTIER)
- class 7 (C7) Project Assignment (optional)
  - Final Project Assignment

Trustworthy AI: Learning from Data with Safety, Fairness, Privacy, and Interpretability Requirements

Scientific Disciplinary Sector: ING-INF/05

Number of hours: About 20

Credits: 5

AIMS AND CONTENT

Learning Outcomes (short)

Students will acquire the basic notions of Trustworthy AI and how it is possible to learn from data with safety, fairness, privacy, and interpretability requirements.

Learning Outcomes (further info)

It has been argued that Artificial Intelligence (AI) is experiencing a fast process of commodification. This characterization is of interest for big IT companies, but it correctly reflects the current industrialization of AI. This phenomenon means that AI systems and products are reaching the society at large and, therefore, that societal issues related to the use of AI and Machine Learning (ML) cannot be ignored any longer. Designing ML models from this human-centered perspective means incorporating human-relevant requirements such as safety, fairness, privacy, and interpretability, but also considering broad societal issues such as ethics and legislation. These are essential aspects to foster the acceptance of ML-based technologies, as well as to be able to comply with an evolving legislation concerning the impact of digital technologies on ethically and privacy sensitive matters.

Syllabus/Content

- Trustworthy AI;
- Safety in AI: Sensitivity Analysis and Adversarial Learning;
- Fairness in AI: from Pre-, In-, and Post-Processing Models to Learn Fair Representations;
- Privacy in AI: Federated Learning and Differential Privacy;
- Interpretability/Explainability of AI: making models more understandable.