

# Manifesto of Studies - PhD in Electronics, Computer Science and Electrical Engineering

The teaching activities of the doctoral course are organised into three curricula:

*Photonics, Microwave Technologies and Communication Systems*  
*Computer science and Automation*  
*Industrial Engineering*

that correspond to the main research areas within the doctoral faculty. At the enrolment stage, each student of the XXXIX cycle is associated to a curriculum on the basis of his/her background and the theme of the research project assigned by the tutor.

Each student must accumulate a total of at least 10 credits by attending and passing the examinations of the courses proposed by the PhD board.

In agreement with the tutor, the student may include courses from other curricula in his/her teaching plan if these are consistent with the training project.

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## Curriculum Photonics – Microwave Technologies – Communication Systems

### **Theranostic Photonics: Sensing, Diagnostic, and Therapeutic Applications of Lasers**

*Lecturers:* P. Minzioni, V. Bello

With this course we aim to offer an overview of the recent advances in biophotonics. The course will include an initial review to guarantee that all the students have the required knowledge in optics and photonics so that they can fruitfully attend the following lessons on advanced topics. The course will discuss some of the emerging fields in the biophotonics landscape, and will discuss their basic principles and applications

**Course credits: 5 - Topic: Photonics – First semester A.Y. 2023-24**

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## **Courses planned during the Academic Year 2024-25**

### **Numerical methods for the design of photonic and microwave components**

*Lecturers:* M. Bozzi, C. Lacava, A. Agnesi

The purpose of the course is to provide students with numerical skills for the design of photonic and microwave devices and components in the guided propagation regime or in free space. The course also includes presentation and in-depth study of the main software adopted in scientific and commercial applications.

**Course credits: 6,6 – Topics: Photonics, Microwave Technologies**

### **Photonic integrated circuits**

*Lecturer:* M. Sorel - Scuola Sant'Anna (Pisa, Italy) and Glasgow University (UK)

*Objectives:* The course will provide an overview on the main photonic integrated technologies, on their limitations and on the challenges to be addressed to sustain the current growth. We will then introduce a number of basic building blocks such as waveguide couplers, resonators, diffraction gratings, semiconductor sources and detectors, and show how these can be combined to form more complex circuits. Examples will include multiplexers for optical communications, optical combs for atomic clocks, mid infrared chips for pollution sensing and spatial mode sorters for advanced imaging. The course will also illustrate future trends

such as the heterogeneous integration of hybrid materials for novel functionalities, bendable and foldable photonic chips and 3D integrated photonic circuits.

**Course credits: 3 - Topic: Photonics**

### **Artificial Intelligence for photonic applications**

*Lecturers:* M. Piastra, C. Lacava

The course aims at providing the participants with the fundamental elements of the discipline, while also including a practical perspective. The overall objective is to give a good understanding of deep learning from an instrumental point of view, in the perspective of its application in both research and design activities. Although no exercises will be actually performed during class activities, some 'take-away' coding examples will be given and discussed in depth.

**Course credits: 3,4 - Topic: Photonics**

### **Advanced Topics in RF and Microwave Technology**

*Lecturers:* M. Bozzi and L. Perregrini

*Objectives:* The course aims to provide an overview on the emerging research topics in microwave and antenna technology, with particular emphasis on integration and manufacturing technology for RF and microwave components and systems, microwave sensors for material characterization, and industrial and medical applications of microwaves.

**Course credits: 4 - Topic: Microwave Technologies**

### **Polarimetric Synthetic Aperture Radar (SAR) and applications**

*Lecturer:* A. Bhattacharya, Indian Institute of Technology Bombay, Mumbai, India

Main objective of the course: acquire theory and intuition on techniques for processing multivariate time series of measurements, develop understanding of radar/target interaction in spaceborne Earth monitoring. Learn about multi-temporal vegetation monitoring.

**Course credits: 4 - Topics: Communication Systems, Microwave Technologies**

### **Statistical analysis of temporal sequences**

*Lecturer:* A. Frery, Victoria University of Wellington, New Zealand

Main objective of the course is to develop intuition and practical skills to analyze time series in a modern computational environment.

**Course credits: 6 - Topic: Communication Systems**

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## **Curriculum Computer Science and Automation**

### **3D Computer Graphics**

*Lecturers:* P Dondi, A. Gaggia (BeSharp)

The main objective of the course is to introduce the basic principles and methods of 3D computer graphics

**Course credits: 3 - Topics: Cyber Physical Systems, Artificial Intelligence and Computer Vision – Second Semester A.Y. 2023-24**

### **AI-Driven Cybersecurity**

*Lecturers and coordinators:* A. Nocera, C. Cusano

Cybersecurity deals with technologies, processes, and control mechanisms to protect devices, networks, and data from malicious attackers. As cyberattacks evolve overtime and grow in volume and complexity, Artificial Intelligence (AI) techniques have shown to be fundamental solutions to stay ahead of threats. Although such

techniques, typically involving machine learning and deep learning solutions, are key factors to develop new generation defense mechanisms, more and more AI-driven menaces are also developed by attackers. This course provides an overview of cybersecurity and privacy concepts, introduces the main technologies adopted in this context, and then shows practical examples of AI-driven attack and defense approaches.

**Course credits: 4 - Topics: Cyber Physical Systems, Artificial Intelligence and Computer Vision – Second Semester A.Y. 2023-24**

### **Embedded systems design, communication and data acquisition**

*Lecturers:* F. Loporati, E. Marenzi, E. Torti

The course addresses the design of digital embedded systems for all those applications into which processing performance should be combined with low power consuming, small footprint and customised resources. Due to the strong interactions with the environments into which these systems are “embedded” these themes are very hot and feature huge connections with several industrial fields (avionics, medicine and bioengineering, food and agriculture, ...) allowing students to have a thorough vision of many disciplines tackled during the MD and PhD studies.

**Course credits: 4,5 - Topics: Cyber Physical Systems – Second Semester A.Y. 2023-24**

### **Probabilistic Graphical Models and Causal Inference**

*Lecturer:* M. Piastra

The objective of this short course is giving a brief account of the theoretical foundations of causal models, describing basic computation methods and giving a few practical examples.

**Course credits: 1,2 - Topics: Artificial Intelligence and Computer Vision – Second Semester A.Y. 2023-24**

### **Real-time Physical Systems (Real-time scheduling for load shifting)**

*Lecturers:* T. Facchinetti

The objective of the course is to illustrate the application of real-time scheduling algorithms to the scheduling of power loads in an energy system, with applications to building automation, load balancing and peak load shaving.

**Course credits: 3 - Topic: Cyber Physical Systems – Second Semester A.Y. 2023-24**

### **Systems and control colloquia I**

*Lecturers:* M. Cucuzzella, G. De Nicolao, A. Ferrara, G. Galuppini, L. Magni, C. Toffanin

The course aims at sharing methodologies and applications used and developed in the Identification and Control of Dynamic Systems Laboratory. A second goal is to improve the PhD students capability to present, discuss and critically evaluate scientific topics. In this respect, the PhD students will be an active part of the teaching through the presentation of their own research and during the open discussion periods. This teaching approach is typical of flipped learning.

**Course credits: 3 - Topic: Automation – Second Semester A.Y. 23-24**

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## **Courses planned during the Academic Year 2024-25**

### **Gaze-Enhanced Intelligent Human-Computer Interaction**

*Lecturer:* M. Porta

Simple and effective communication with the computer is an increasingly relevant requirement, and recent developments in the fields of Artificial Intelligence and machine perception can contribute significantly to this aim. In the context of Intelligent User Interfaces (IUIs), Eye Tracking plays an important role, providing the computer with the sensory capabilities necessary for the perception of the user's gaze.

This short course offers an overview of the characteristics and applications of Human-Computer Interaction (HCI) enhanced by eye input. Through the analysis of existing solutions and current trends, the student will discover the potential of user interfaces that implement gaze-based implicit and explicit communication.

**Course credits: 2,4 - Topics: Artificial Intelligence and Computer Vision**

### Digital Humanities

*Lecturers:* M. Musci, V. Cantoni

The main objective is to introduce to computer engineering students the topic of Digital Humanities, e.g. how modern digital technologies can be employed to preserve, restore, and improve the cultural heritage.

**Course credits: 3,4 - Topic: Artificial Intelligence and Computer Vision**

### Artificial Intelligence Risk Management

*Lecturers:* P. Giudici, E. Raffinetti

The aim of the course is to introduce AI risk management metrics: Accuracy, Robustness, Explainability, Fairness, Sustainability, and show how to calculate them in specific AI applications. This is in line with the recent development in international regulations and standards, such as the EU AI Act and ISO/IEC 22989.

**Course credits: 3 - Topic: Artificial Intelligence and Computer Vision**

### Systems and control colloquia II

*Lecturers:* M. Cucuzzella, G. De Nicolao, A. Ferrara, G. Galuppini, L. Magni, C. Toffanin

The course aims at sharing methodologies and applications used and developed in the Identification and Control of Dynamic Systems Laboratory. A second goal is to improve the PhD students capability to present, discuss and critically evaluate scientific topics. In this respect, the PhD students will be an active part of the teaching through the presentation of their own research and during the open discussion periods. This teaching approach is typical of flipped learning.

**Course credits: 3 - Topic: Automation**

### A Smart Grid for Energy Management: the IoT approach

*Coordinators:* P. Di Barba, F. Benzi

The course aims at giving a general overview of systems and devices, characterizing the smart grid, as well as an insight on models, algorithms and strategies for the optimal distribution of energy resources. This issue is of very current interest and in evolution, thanks to recent enabling technologies (IIoT approach, cloud data, novel control strategies).

**Course credits: 7,4 - Topic: Automation**

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## Curriculum Industrial Engineering

### Industrial programming

*Coordinator:* H. Giberti

The objective of this course is to deepen the understanding of a range of programming languages and to obtain a critical understanding of the outstanding features of each of the languages.

**Course credits: 4 - Topic: Mechatronics and Robotics – Second semester A.Y. 2023 – 24**

### **Real-time Physical Systems (Real-time scheduling for load shifting)**

*Lecturers:* T. Facchinetti

The objective of the course is to illustrate the application of real-time scheduling algorithms to the scheduling of power loads in an energy system, with applications to building automation, load balancing and peak load shaving.

***Course credits: 3 - Topic: Electrical Engineering –Second semester A.Y. 2023 - 24***

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### ***Courses planned during the Academic Year 2024-25***

#### **A Smart Grid for Energy Management: the IoT approach**

*Coordinators:* P. Di Barba, F. Benzi

The course aims at giving a general overview of systems and devices, characterizing the smart grid, as well as an insight on models, algorithms and strategies for the optimal distribution of energy resources. This issue is of very current interest and in evolution, thanks to recent enabling technologies (IIoT approach, cloud data, novel control strategies).

***Course credits: 7,4 - Topic: Electrical Engineering***

#### **Statistical analysis of temporal sequences**

*Lecturer:* A. Frery, Victoria University of Wellington, New Zealand

Main objective of the course is to develop intuition and practical skills to analyze time series in a modern computational environment.

***Course credits: 6 - Topic: Mechatronics and Robotics***

#### **Advanced Robotics**

*Coordinator:* H. Giberti

The aim of the course is to provide an overview of robotics frontier technologies and applications mainly for the industrial sector.

***Course credits: 4 - Topic: Mechatronics and Robotics***