Course title	Distributed/Decentralized Control and Optimization of Large-Scale Systems
Scientific Discipline Sector	ING-INF/04
Professor	Raffaele Carli
mail	raffaele.carli@poliba.it
CFU	1 CFU
SUMMARY /GOAL	This course aims at providing PhD students with modeling and methodological tools for formulating and solving large-scale optimization problems with a focus on the use of duality theory. During the course several optimization problems will be formalized, particularly referred to relevant issues within management and industrial engineering. Problem definition and resolution will be also implemented in simulation and engineering software (Matlab). The final goal is to provide PhD students with the necessary background for starting research in the field of duality-based decentralized and distributed optimization techniques to be applied to large-scale systems. Each lesson consists in lectures, numerical examples, simulation and analysis of case studies.

Course title	Non-integer order systems and controllers
Scientific Discipline Sector	ING-INF/04
Professor	Guido Maione
mail	guido.maione@poliba.it
CFU	1 CFU
SUMMARY /GOAL	The course concerns non-integer-order systems. These systems can propose engineering solutions to modeling and control problems that often improve those based on integer-order calculus. Basic tools of fractional calculus are introduced, and some methods and models are described for different engineering fields. Models for practical applications are proposed. Moreover, approaches to design and realize non-integer-order (fractional-order) controllers are described. These controllers show higher flexibility, increased robustness, and ability to obtain a better trade-off between stability and dynamic performance with respect to widespread PID controllers. As case-studies, the course uses applications in automotive and mechatronic systems.

Course title	Deep Reinforcement Learning for Control of Autonomous Systems
Scientific Discipline Sector	ING-INF/04
Professor	
mail	
CFU	1 CFU
SUMMARY /GOAL	Reinforcement learning deals with solving sequential decision problems when minima prior information is available. Solving sequential decision problems means finding their optimal control policies. Using reinforcement learning algorithms, the optimal policy is learned through the cooperation between the agent (or controller) and the system to be controlled. Deep Reinforcement Learning (DRL) is a subfield of machine learning that combines reinforcement learning (RL) and deep learning. The course will propose the main modeling frameworks, investigate the most relevant deep reinforcement learning techniques and show some interesting applications.

Course title	Control and Security of Cyber Physical Systems
Scientific Discipline Sector	ING-INF/04
Professor	
mail	
CFU	1 CFU
SUMMARY /GOAL	The aim of the course is to show the importance of control and security in Cyber Physical Systems (CPSs). CPSs are systems where a decision making(cyber/control) component is tightly integrated with a physical system (with sensing/actuation) to enable real-time monitoring and control. Therefore, control and security are crucial issues for commissioning these systems and for improving competitiveness of companies. In this context, the study of opacity is a fundamental notion to determine if an industrial "secret" can be discovered by a malicious observer (intruder).

Course title	Simulation Systems for Engineering Applications
Scientific Discipline Sector	ING-INF/04
Professor	Raffaele Carli
mail	raffaele.carli@poliba.it
CFU	1 CFU
SUMMARY /GOAL	The course shall address the basis of simulation techniques for engineering applications, with a focus on the underlying mathematical formalism. At end of this course students will be able to deal with system modeling and to implement simulation models in engineering tools (e.g., Python, Matlab). Each lesson shall consist in lecture and numerical examples.

Course title	Simulation, optimization, and management of smart energy systems
Scientific Discipline Sector	ING-INF/04
Professor	Michele Roccotelli
mail	michele.roccotelli@poliba.it
CFU	1 CFU
SUMMARY /GOAL	The course will focus on models, techniques and tools for the simulation and optimization of energy systems in smart buildings and smart mobility applications. At the end of this course students will achieve the basics for modeling and simulating such energy systems using engineering tools (e.g., Matlab, SUMO). Each lesson will consist in lecture and software exercises.

Course title	Game Theory for Controlling Autonomous Systems
Scientific Discipline Sector	ING-INF/04
Professor	Paolo Scarabaggio
mail	paolo.scarabaggio@poliba.it
CFU	1 CFU
SUMMARY /GOAL	This course is designed to provide PhD students with the necessary modeling and methodological tools for analyzing and designing algorithms to solve game equilibrium problems. The course will include lectures, numerical examples, simulations, and analysis of case studies.

Course title	Modeling and simulation of biosystems
Scientific Discipline Sector	ING-INF/04
Professor	Alessandro Borri
mail	alessandro.borri@iasi.cnr.it
CFU	2 CFU
SUMMARY /GOAL	This course provides mathematical tools to model, analyze, simulate and control biological and medical systems, exploiting both deterministic and stochastic frameworks. At end of this course, the students will be able to deal with system modeling and to implement simulation models in Matlab.

Course title	Dynamical stochastic models of biological systems
Scientific Discipline Sector	ING-INF/04
Professor	Pasquale Palumbo
mail	pasquale.palumbo@unimib.it
CFU	1 CFU
SUMMARY /GOAL	This course gives the mathematical tools to model and analyze most common biological frameworks such as chemical reactions and gene transcription networks, according to the stochastic approach of the Chemical Master Equations.

Course title	Data-driven fault diagnosis and fault prognosis
Scientific Discipline Sector	ING-INF/04
Professor	Francesco Ferracuti
mail	f.ferracuti@univpm.it
CFU	1 CFU
SUMMARY /GOAL	This module aims at providing PhD students with the main concepts of data-driven fault diagnosis and fault prognosis which are at the base of modern condition-based and predictive maintenance. During the module, the students will learn how to apply a data-driven workflow to solve real case studies and to adapt it to the specific cases of fault diagnosis and fault prognosis. The workflow will include data processing, feature extraction and model training, with some insights on deployment complexity; problem resolution will also be implemented by using a common engineering software (MATLAB). The final goal is to provide PhD students with the necessary background to process sensors data and use them to monitor the condition of a physical system, classify possible undesired behaviours and eventually estimate the remaining useful life of specific components. Each lesson consists in lectures, numerical examples and analysis of case studies.

Course title	Gaussian processes for modeling and control of robotics systems
Scientific Discipline Sector	ING-INF/04
Professor	Alberto Dalla Libera
mail	alberto.dallalibera@unipd.it
CFU	2 CFU
SUMMARY /GOAL	The course shall address the basis of Gaussian Process Regression applied to modeling and control of robotic manipulators. At end of this course, students will be able to apply Gaussian Process Regression to the following problems: ▪ Inverse dynamics identification; ▪ Estimation of forward dynamics model to simulate the evolution of a robotic system; ▪ Use such models to derive a controller. Lesson shall consist in lecture and numerical examples in MATLAB and Python.

Course title	Human autonomous system interaction
Scientific Discipline Sector	ING-INF/04
Professor	Sabrina Iarlori
mail	s.iarlori@staff.univpm.it
CFU	1 CFU
SUMMARY /GOAL	The course aims at providing PhD students with the main concepts of the well-known technology for improving human-autonomy interaction with a special focus on autonomous systems. It is especially focused on technology and case studies relevant to complex, applied environments in which people interact with autonomous systems regularly, particularly in the context of ambient assisted living. The course focuses on approaches that include task inputs from humans: how to model humans and their tasks and at what level of details. Moreover, the human in-the loop approach will be introduced as a new scenario to facilitate the goal achievement, to reduce the anomalies and the unexpected responses from the system or inappropriate responses by the human to enhance human safety. New human-system engineering techniques are needed to ensure autonomous systems will be smoothly and readily adopted into society. Autonomous systems that work together in the environment should integrate the connections and interactions between them, over networks, with the physical environment, and with humans must be assured, resilient, productive, and fair in the autonomous future. Autonomous systems should be analysed including concept, context, requirements, design, integration, operationalization, validation, testing and evaluation. During the course, the students will learn how the human-autonomous system interaction is achieved and how it is articulated. The workflow will include data processing, feature extraction and model training for human-robot interaction tasks, with some insights on deployment complexity; problem resolution will also be proposed by using a common engineering software (MATLAB), and the ROS (Robot Operating System). Each lesson consists in lectures, numerical examples and analysis of case studies.

Course title	Intelligent Supervisory Systems
Scientific Discipline Sector	ING-INF/04
Professor	Silvio Simani
mail	silvio.simani@unife.it
CFU	2 CFU
SUMMARY /GOAL	This course aims to offer a foundation of intelligent supervisory system techniques and their application in various real-world domains and how to implement a solution with “intelligent” functionality. Students will learn to judge when intelligent functionality and artificial intelligence may be a good solution for a problem and be able to choose suitable artificial intelligence methods and techniques. Students will also acquire knowledge enabling them to develop the necessary skills to design and implement an intelligent supervisory system.

Course title	Introduction to autonomous systems
Scientific Discipline Sector	ING-INF/04
Professor	Sauro Longhi
mail	s.longhi@staff.univpm.it
CFU	1 CFU
SUMMARY /GOAL	The course aims at providing PhD students with the fundamental principles, technologies, and applications related to autonomous systems.

Course title	Linear algebra for control applications
Scientific Discipline Sector	ING-INF/04
Professor	Matthias Pezzutto
mail	matthias.pezzutto@unipd.it
CFU	2 CFU
SUMMARY /GOAL	The course will introduce advanced linear algebra tools that are commonly used in many applications in Control and System Theory. The course will address this topic from different perspective: 1. Theory with formal proofs of many results, 2. Algorithms to understand the most common algorithms used in MATLAB or Python for linear algebra, 3. Implementation via MATLAB of algorithms and performance evaluation on large data sets.

Course title	Linear and nonlinear Kalman filtering: theory and applications
Scientific Discipline Sector	ING-INF/04
Professor	Luigi Chisci
mail	luigi.chisci@unifi.it
CFU	2 CFU
SUMMARY /GOAL	This course aims to provide both theoretical and practical tools to tackle estimation problems encountered in several areas of engineering and science. In particular, it is shown how to formulate such estimation problems as instances of a general dynamical system state estimation problem and how to derive the mathematical solution of the latter problem. Then it is shown that, for a linear Gaussian system, such a solution yields the well known Kalman filter. Further, approximate techniques (e.g. extended and unscented Kalman filters, particle filter, etc.) are presented for the case of nonlinear and/or non-Gaussian systems, for which an exact closed-form solution cannot be found. To conclude the theoretical part, theoretical limitations (i.e. the Cramer-Rao lower bound) on the quality of estimation are discussed. In the final part of the course, we illustrate some applications of linear/nonlinear Kalman filtering (e.g., tracking, robotic navigation, environmental data assimilation).

Course title	Optimal control for climate change and air quality
Scientific Discipline Sector	ING-INF/04
Professor	Claudio Carnevale
mail	claudio.carnevale@unibs.it
CFU	2 CFU
SUMMARY /GOAL	The course will address the fundamentals of the modelling and control of real-world systems, presenting the application of control theory to climate change and air quality. Each lesson shall consist in lecture and numerical examples.

Course title	Learning in multi-agent systems
Scientific Discipline Sector	ING-INF/04
Professor	Nicola Bastianello
mail	nicolba@kth.se
CFU	2 CFU
SUMMARY /GOAL	The aim of the course is to provide a thorough overview of learning and optimization in multi-agent systems. At the end of the course, students will be familiar with applications, with the challenges of decentralized learning, and the current state-of-the-art solutions. Additionally, they will have an overview of current research trends and opportunities. Lessons will merge theoretical lectures and numerical examples (using Python).

Course title	Non-linear control
Scientific Discipline Sector	ING-INF/04
Professor	Karl Dietrich von Ellenrieder
mail	karl.vonellenrieder@unibz.it
CFU	2 CFU
SUMMARY /GOAL	The course introduces analytical tools for the analysis and design of nonlinear control systems. At the end of the course students will understand how to analyze the stability of nonlinear dynamic systems and knowledge of some of the main approaches for designing nonlinear controllers. Basic engineering examples and Matlab exercises are provided.

Course title	Variable structure control
Scientific Discipline Sector	ING-INF/04
Professor	Elio Usai
mail	elio.usai@unica.it
CFU	1 CFU
SUMMARY /GOAL	Variable Structure Control (VSC) is a control technique who force a dynamical system to behave as a Variable Structure System (VSS) whose characteristics satisfy the required performance, in spite of a class of uncertainties in the system dynamics and external disturbances. In particular the system is forced to reach and remain constrained onto a properly chosen surface of the state space such that the movement on such a surface, i.e., the Sliding Mode (SM), is invariant and corresponds to specifications. The lectures will present the general theoretic and applicative framework of VSC with SMs, presenting it in the more general vision of the control systems. Some of the mathematical tools to analyze and design a VSC with SM will be presented and discussed, also by means of simple examples. The limits of the resulting switching control, the tools to analyze the approximate behavior and the approaches to mitigate the so-called chattering phenomenon will be presented and discussed. Finally, some applications of VSC to real systems and to observer design will be presented.