Robotics and Automation Engineering
Student Information Booklet

Academic Year 2021-2022

PLANNED TEACHING OFFER – ACADEMIC YEAR 2021/2022

1. **The course in a nutshell**

The Master's Degree Course in Robotics and Automation Engineering focuses with the instruction of Engineers with specific skills on intelligent autonomous systems, autonomous and cognitive robotics and cyber-physical systems.

The course provides an adequate background both on the methodological principles of the Automation theory (Feedback Control Theory, Optimization, Estimation and Filtering) and on the practical/technological aspects of industrial and information engineering frameworks (robotics and mechatronics, computer science and principles of real-time programming for automation systems, control of networked systems, intelligent learning, localization and autonomous driving) as a cultural background supplement of the Engineer in Robotics and Automation.

The course belongs to the Information Engineering degree class but, compared to other job roles coming from this field, the Robotics and Automation Engineer has a wide range of knowledge related also to Robotics and Industrial Engineering.

The course main aims are then to train an Engineer with a technical-scientific profile focused both on the information methodologies and on the most advanced techniques related to autonomous and Human-in-the-loop Robotics for advanced applications.

The Robotics and Automation Engineer id therefore endowed with a strong interdisciplinary vision (capability to merge all the necessary methodologies/technical aspects related to a given task) and is flexibile enough to adapt to changed working conditions following scientific and technical/industrial advancements. These features allow the Robotics and Automation Engineer to join and / or to lead, on the basis of experience gained, the design and management phases of an entire automation system and to provide high-skilled technical advice on the planning and operational management.

The study programme includes two curricula: *Intelligent Autonomous Systems* and *Cyber-Physical Systems.*

The *Intelligent Autonomous Systems* Curriculum focus on the design and supervision of intelligent units that can be used in the industrial and civil sectors to give to the Robotics and Automation Engineer the necessary methodological and technological skills. In particular, autonomous vehicles (platoon- or single-based units) performing tasks in potentially dangerous environments are analyzed with the aim of integrating control, computation and communication capabilities.

The *Cyber-Physical Systems* Curriculum aims instead to give to a Robotics and Automation Engineer significant skills in modeling, supervision and control of the so-called Cyber-Physical Systems (CPS) which represent paradigms where sensor networks are combined in a tightly integrated fashion with actuators, local and / or geographic networks (Internet) for data transmission, distributed data processing, control actions computation and plants consisting of interconnected and geographically distributed systems.

2. Official Teaching Activities for Full-Time Students

Intelligent Autonomous Systems Course of Studies

Year	Semester	Classroom	Credits
1	I	Dynamical Systems Theory	9
1	I	Industrial Automation and Optimal Control – Module 1 – Industrial Automation	6
1	I	Vechicle Dynamics	6
1	I	Optimization Methods for Control Theory	6
1	II	Industrial Automation and Optimal Control – Module 2 – Optimal Control	6
1	II	Networked Control Systems	6
1	II	Filtering and Identification of Dynamical Systems	6
1	II	Embedded Systems - Module 1: Embedded Systems Programming	6
1	II	Embedded Systems - Module 1: Embedded Feedback Control Systems	3
2	I	Autonomous Multi-Agent Control Systems	6
2	I	Vehicles Control - Module 1: Model Based Control Schemes	6
2	I	Vehicles Control- Module 2: Autonomous Driving Vehicle Models	3
2	I	Mobile Robotics - Module 1 : Autonomous Robotics	6
2	I	Mobile Robotics - Module 2 : Cognitive Robotics	3
2	I	Free Credits	6
2	II	Machine Learning	6
2	II	Free Credits	6
2	II	Final Dissertation	21

3. Classrooms Syllabus:

Classroom	Dynamical Systems Theory
Credits	9
Learning Objectives	The course aims at introducing students to the topic of mathematical modeling of dynamic systems, the analysis of their responses and stability properties and the problem of their control. Starting with examples from physics, hydraulics, demography, electromagnetic, etc. it will show how the mathematical models arising for systems of different physical domains present similarities, or even coincide, and motivate the opportunity of the development of a general systems theory for their study. These models will be used to explain or predict the time evolution of relevant variables and to analyze the stability properties of the system. Wherever possible (linear models) this will be done analytically. On the contrary, when this cannot be done (nonlinear models) numerical simulations will be used. Finally, the student will be introduced to the basic problems of multi-variable control of dynamical systems, the more used control objectives and the limits of achievable performance.
Prerequisites	None

Classroom	Industrial Automation and Optimal Control – Module 1 – Industrial Automation
Credits	6
Learning Objectives	The course provides a vision system processes the supervisory and control dedicated to the operation of machines and apparatuses interdependent, integrated with computer systems that operate on a distributed communication network capable of performing in real time the expected sequence of basic functions, such as acquisition , conditioning, diagnosis, development and implementation.
Prerequisites	None

Classroom	Industrial Automation and Optimal Control – Module 2 – Optimal Control
Credits	6
Learning Objectives	The course aims to provide the tools for analysis and design of control systems based on optimality criteria. The student will be able to analyze and to design an optimization based feedback control algorithm also by means of semidefinite programming algorithms.
Prerequisites	Dynamical Systems Theory

Classroom	Vehicle Dynamics
Credits	6
Learning Objectives	The course main aim is to provide the basics of road vehicle dynamics using physical-analytical models obtained in a deductive fashion. Problems related to the tire-road interaction, longitudinal, lateral and vertical dynamics of the vehicle are addressed.
Prerequisites	None

Classroom	Optimization Methods for Control Theory
Credits	6
Learning Objectives	To provide theoretical basis of Mathematical Programming. To introduce the most important classes of numerical algorithms for both unconstrained and constrained minimization of functions of several variables.
Prerequisites	None

Classroom	Networked Control Systems
Credits	6
Learning Objectives	This course offers an introduction to control systems using communication networks for interfacing sensors, actuators, controllers, and processes. Challenges due to network non-idealities and opportunities offered by communication will be analyzed.
Prerequisites	Dynamical Systems Theory

Classroom	Filtering and Identification of Dynamical Systems
Credits	6
Learning Objectives	The course provides a solid theoretical basis and a wide range of algorithmic tools for solving problems in which the signals involved in a control loop are modeled by stochastic processes.
Prerequisites	Dynamical Systems Theory

Classroom	Embedded Systems - Module 1: Embedded Systems Programming
Credits	6
Learning Objectives	The course introduces the basic concepts of embedded systems programming and the problems of interfacing with external devices. The used programming languages are: the assembler of the AVR 8-bit microcontroller and C.
Prerequisites	None

Classroom	Embedded Systems - Module 2: Embedded Feedback Control Systems
Credits	3
Learning Objectives	The course introduces the problems related to the implementation of automatic control schemes on microcontrollers-based platforms. Specifically, the course covers the operation of the embedded operating systems for real-time applications and their use in the development of automatic control applications.
Prerequisites	None

Classroom	Autonomous Multi-Agent Control Systems
Credits	6
Learning Objectives	The course provides a methodological description of feedback control constrained strategies. In particular, predictive control schemes are analyzed and tested processes of physical-industrial. The main objective of the course is to provide an overview as complete as possible of the strategies of predictive nature of the latest generation. In addition, a second important goal is to make possible the testing of the above techniques in the laboratory of systems (LSA) of the autonomous DIMES.
Prerequisites	Dynamical Systems Theory

Classroom	Vehicles Control - Module 1: Model Based Control Schemes
Credits	6
Learning Objectives	The course aims at showing the main components and subsystems of modern automotive vehicles, their mathematical models and the main control problems aimed at obtaining good performance such as stability, safety, energy saving and drive comfort. A further part of

	the course concerns the study of optimal and gain-scheduling control techniques of interest for the control of vehicles and engines.
Prerequisites	Dynamical Systems Theory

Classroom	Vehicles Control- Module 2: Autonomous Driving Vehicle Models
Credits	3
Learning Objectives	The course aims at showing the main components and subsystems of modern advanced driver assistance systems (ADAS) and autonomous vehicles, their mathematical models and the main control problems aimed at obtaining good performance such as stability, safety and drive comfort. A further part of the course concerns the study and the use of software for algorithms design for path planning and autonomous and assisted systems control.
Prerequisites	Dynamical Systems Theory

Classroom	Mobile Robotics - Module 1 : Autonomous Robotics
Credits	6
Learning Objectives	The aim of this course is to introduce the student to the fundamental aspects of modelling, planning and control for mobile and autonomous robots, and mobile manipulators. The course covers the main aspects of mobile robotics and mobile manipulation, making reference to indoor, outdoor and off-road environments. Classical and modern planning and control techniques are introduced.
Prerequisites	Networked Control Systems

Classroom	Mobile Robotics - Module 2 : Cognitive Robotics
Credits	3
Learning Objectives	The course main aim is to provide the architectural, methodological and design elements for the construction of intelligent robots. In particular, the main topics focuse on the high-level robot sensor capabilities (interpretation of the scene based on 2D and 3D robotic vision, speech understanding) and cognitive features (recognition of actions and gestures, automatic learning of complex behaviors, interpretation of the structure of the environment and interaction with other robots and human subjects).
Prerequisites	Networked Control Systems

Classroom	Machine Learning
Credits	6
Learning Objectives	This course provides a broad introduction to machine learning and statistical pattern recognition. Topics include: supervised learning (generative/discriminative learning, parametric/non-parametric learning, neural networks, support vector machines); unsupervised learning (clustering, dimensionality reduction, kernel methods); learning theory (bias/variance tradeoffs, practical advice); reinforcement learning and adaptive control. The course will also discuss recent applications of machine learning, such as to robotic control, data mining, autonomous navigation, bioinformatics, speech recognition, and text and web data processing.
Prerequisites	None