UNIVERSITÀ DEGLI STUDI DI PALERMO

DEPARTMENT	Ingegneria
ACADEMIC YEAR	2018/2019
MASTER'S DEGREE (MSC)	ELECTRONIC ENGINEERING
SUBJECT	MOBILE AND COOPERATING ROBOTIC SYSTEMS
TYPE OF EDUCATIONAL ACTIVITY	C
AMBIT	20925-Attività formative affini o integrative
CODE	19695
SCIENTIFIC SECTOR(S)	ING-INF/04
HEAD PROFESSOR(S)	FAGIOLINI ADRIANO Professore Associato Univ. di PALERMO
OTHER PROFESSOR(S)	
CREDITS	6
INDIVIDUAL STUDY (Hrs)	108
COURSE ACTIVITY (Hrs)	42
PROPAEDEUTICAL SUBJECTS	
MUTUALIZATION	MOBILE AND COOPERATING ROBOTICS - Corso: AEROSPACE ENGINEERING MOBILE AND COOPERATING ROBOTICS - Corso: INGEGNERIA AEROSPAZIALE
YEAR	1
TERM (SEMESTER)	1° semester
ATTENDANCE	Not mandatory
EVALUATION	Out of 30
TEACHER OFFICE HOURS	**FAGIOLINI ADRIANO** Tuesday 16:00 20:00 - Edificio 10, Viale delle Scienze, Ufficio Docente- Canale Teams

DOCENTE: Prof. ADRIANO FAGIOLINI

PREREQUISITES	Basic knowledge of Physics (in particular of Mechanics and Electromagnetism), Vector and matrix calculus fundamentals (sum, scalar and vector product, property of matrix operations, matrix determinant, trace, and eigenvalues), System Theory (state form, inputs, outputs, transfer functions), notions of automatic controls (simple proportional compensation networks, integral, derivative).
LEARNING OUTCOMES	The main objective of the course is the study of robotic systems with fixed and mobile bases, and their exploitation in the industry as well as in the services.
ASSESSMENT METHODS	Written and oral exams. The written exam must be completed within 3 hours. Its aim is that of assessing the required student's ability, skills and competences. The oral exam aims at evaluating the student's ability to correctly express all notions discussed during the course, by using the relevant scientific language.
EDUCATIONAL OBJECTIVES	Class lessons, works, and laboratory. The course is organized into two modules. The first module aims at providing the students with the theoretical tools for the study of the properties of nonlinear dynamical systems and for the design of nonlinear controllers, under knowledge of the nominal behavior of some mobile robots. Moreover, the course has the objective of instructing the students with the use of software tools, mainly Matlab/ Simulink, for the simulation of dynamic models, as well as the implementation of controllers by means of electronic boards for rapid prototyping. The second module has the aim of providing students with the basic technological knowledge in the field of industrial robotics, illustrating the main issues related to the use of robots in industry and allowing them to acquire skills in the use and programming of robots.
TEACHING METHODS	Students will know the methodologies for the derivation of kinematic and dynamic models of the robot, for the planning of the trajectories and for the design of the control systems. Furthermore, they will know the operation of basic instructions of a robot programming language. At the of the course the students will be able to apply the modeling methods learned in the course to specific robots, and to implement simulation programs. Students will be able to evaluate and choose the type of robot and the most appropriate control procedures for the execution of a certain activity or industrial processing. Students will be able to discuss and explain both the technical and non-technical about the feasibility of using robots for specific applications, and illustrate the advantages and disadvantages. They will have finally gained the ability to read and understand advanced robotics texts.
SUGGESTED BIBLIOGRAPHY	• Dispense fornite dal docente / Lecture notes provided by the teacher • L. Sciavicco, B. Siciliano, L. Villani, G. Oriolo, Robotica, McGraw-Hill, 3 a edizione, 2008 • Hassan K. Khalil , Nonlinear Systems, 3° edizione, Prentice Hall. • Siegwart, Nourbakhsh, Introduction to Autonomous Mobile Robots, MIT Press, 2010.

SYLLABUS

Hrs	Frontal teaching
2	1.1 "Introduction to Mobile Robotics". Applications in the industry and for services.
4	1.2 "Recalls of analysis of nonlinear dynamic systems". State forms. Equilibria and stability. Lyapunov's methods, Babarshin-Krasovskii's Theorem. Variable gradient method. Invariant Sets and Krasovskii-Lasalle's Theorem. Limit Cycles.
6	1.3 "Control tools for nonlinear dynamic models". Lyapunov Control Functions. Backstepping. SISO exact input-output linearization.
6	1.4 "Wheeled Robots". Nonholonomic systems and canonical forms. Unicycle vehicles (kinematic and dynamic models, point-to-point motion control, control law for path following and trajectory tracking). Car-like vehicles (rear and front traction, rear and front reference kinematic models, dynamic models, controllers for path following and automatic parking).
6	2.1 "Race-cars". Mechanics of the wheel and tyre. Tire slips. Magic formula. Components of the vehicle model (kinematics, road-tyre interaction, load transfers, first-order suspension, insights on braking). Single track model (nonlinear). Linear control for constant forward speed and/or lateral wind gusts. Double track model. Control of roll motion and lateral velocity. Model predictive control (MPC) for classes of trajectories. Optimal trajectory planning (minimum length, minimum curvature, mixed solutions).
6	2.2 "Autonomous Aircrafts". Applications. Mechanics, underactuation, and dynamic model of a quadrotor. Linear cascade control of attitude and position at hovering. Recalls of nonlinear controllers for tracking acrobatic trajectories.
4	3.1 "Distributed Robots". Recalls on graph theory. Message-based cooperation. The linear consensus algorithm. Coordination for rendez-vous, coverage, and formation control. Voronoi partitions.
2	3.2 "ROS (Robot Operating System)". Software architecture. MAVLINK protocol. Programming with Matlab/ Simulink and Software In The Loop (SITL).

SYLLABUS

Hrs	Frontal teaching
6	3.3 "Advanced mathematical analysis and control tools. Reachability and observability for nonlinear systems, Lie products and brackets, involutive distributions. MIMO exact input-output linearization. Adaptive control and online parameter estimation. Backstepping adaptive control.

Hrs	Practice
2	Stability analysis of equilibria for nonlinear systems of 2nd and 3rd order. Direct Lyapunov's method applied to wheeled mobile robots.
2	Model predictive control (MPC) of race-cars in TORCS. Quadrotors control in Matlab/Simulink.
2	Hardware in the loop emulation of control systems with ROS/Gazebo and fast prototyping boards (Arduino, ST-microelectronics, Raspberry).