UNIVERSITÀ DEGLI STUDI DI PALERMO

DEPARTMENT	Ingegneria
ACADEMIC YEAR	2023/2024
MASTER'S DEGREE (MSC)	AEROSPACE ENGINEERING
SUBJECT	MOBILE AND DISTRIBUTED ROBOTICS
TYPE OF EDUCATIONAL ACTIVITY	C
AMBIT	20907-Attività formative affini o integrative
CODE	21526
SCIENTIFIC SECTOR(S)	ING-INF/04
HEAD PROFESSOR(S)	FAGIOLINI ADRIANO Professore Associato Univ. di PALERMO
OTHER PROFESSOR(S)	
CREDITS	6
INDIVIDUAL STUDY (Hrs)	96
COURSE ACTIVITY (Hrs)	54
PROPAEDEUTICAL SUBJECTS	
MUTUALIZATION	MOBILE AND DISTRIBUTED ROBOTICS - Corso: CYBER-PHYSICAL SYSTEMS ENGINEERING FOR INDUSTRY MOBILE AND DISTRIBUTED ROBOTICS - Corso: INGEGNERIA DEI SISTEMI CIBER-FISICI PER L'INDUSTRIA
YEAR	2
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	Automatic Control, basic programming in Matlab or C++.
LEARNING OUTCOMES	The main teaching objective of the course is the study of mobile robotic systems (ground or airborne) and their use in various application contexts in industry and services. This objective is achieved through the treatment of non-linear mathematical models, the theoretical tools that allow their analysis and some basic techniques for their control. These tools are then applied to the study of the dynamic behaviour of the robots most commonly used today, and to the control of their movement in the presence of sub-implementation and autonomy constraints. Finally, through the definition of procedures and methodologies for trajectory planning, those systems are described that allow the use of autonomous vehicles or aircraft, for applications characterised by structured or unstructured environments. * Knowledge and understanding The student, at the end of the course, will have acquired knowledge and understanding of mobile robotic systems (ground or airborne) and their use in various application contexts in industry and services. Knowledge and understanding skills are acquired through participation in lectures and tutorials and through personal study and are tested during the examination by asking students to present the topics covered during the course. * Ability to apply knowledge and understanding The student will be able to analyse non-linear mathematical models, the theoretical tools that allow their analysis and some basic techniques for their control. The ability to apply knowledge and understanding is acquired through the study of applications to practical cases presented in the lectures and the performance of practical exercises carried out also with the support of dedicated computer tools. These skills are assessed through examinations, by means of questions requiring the student to extrapolate what has been learnt in class and to apply it to practical cases. * Autonomy of judgement The student will have the ability to interpret, predict and control the dynamic behaviour of the robots most commonly used today. Furthermore, he/she will have the ability to integrate knowledge and make judgements on the basis of limited or incomplete information. * Communication skills The student will be able to communicate the results of verification and testing activities, the procedures used, the underlying rationale and conclusions, including through test reports and reports, clearly and unambiguously to specialist and non-specialist interlocutors. He/she will be able to report the results of process control, acceptance testing and reliability testing of components or systems with competence and propriety of language. * Learning skills The student will develop the learning skills necessary to undertake subsequent studies with a high degree of autonomy, enabling him/her to address any problem related to the definition of procedures and methodologies for trajectory planning; systems enabling the use of autonomous vehicles or aircraft, for applications characterised by structured or unstructured environments, are described.
ASSESSMENT METHODS	Students will learn the methodologies used to derive kinematic and dynamic models of a robot, to plan suitable trajectories and to design a suitable control law. In addition, they will know how the basic instructions of a robot programming language work. At the end of the course, students will be able to apply the modelling methods learned in the course to specific robots and to implement simulation programmes. Students will be able to evaluate and choose the most appropriate type of robot and control procedures to perform a specific task or industrial processing. Students will be able to discuss and explain, both from a technical and non-technical point of view, the feasibility of using robots for specific applications, illustrating their advantages and disadvantages. Finally, they will have acquired the ability to read and understand advanced robotics texts. The assessment of learning takes place through the project and its presentation, which aim to evaluate - the knowledge and understanding of the course content - the ability to apply knowledge to problems and applications in specific areas of the course and/or related to it - ability to link and rework one's own knowledge and to orient oneself and make judgements in disciplinary and/or interdisciplinary contexts; - property of language and clarity of exposition, writing and argumentation. The assessment is expressed in thirtieths and the pass mark is 18/30. The awarding of the grade depends on the overall level of achievement. The elements that contribute to the formation of the grade are as follows: * 28-30 with honours - Full mastery of content: absence of errors; correction of inaccuracies or integration of answers in an autonomous manner; correct and

	rigorous approach to problems; complete, correct and effective solutions; elements of originality; effective reworking of knowledge, autonomy and coherence in orienting oneself or in expressing judgements in disciplinary/ interdisciplinary contexts; excellent clarity of exposition, articulate arguments; full ownership of language. * 24-27 - Good mastery of content: few minor errors/omissions, partially guided corrections/integrations; good problem setting, substantially correct solutions; good coherence in linking concepts and in orienting oneself in disciplinary or related fields; good clarity of exposition, correct ownership of language. * 18-23 - Sufficient knowledge of contents: acceptable approach to problems, overall adequate solutions; limited autonomy, not serious errors/omissions; coherence in orienting and linking concepts in disciplinary fields, even if in an uncertain and guided way; sufficient ownership of language, acceptable exposition. - Less than 18 - Insufficient learning outcomes: at the end of the first half of the course, there is an in itinere test consisting of a written assignment with open questions on the part of the programme already covered. The purpose of this test is to make students aware of their preparation and its result does not count towards the final grade.
EDUCATIONAL OBJECTIVES	The first educational objective of the course is to provide the theoretical tools for the study of non-linear dynamic models, for the design of non-linear controllers, in conditions of nominal knowledge of the model, and for their validation with respect to model disturbances and uncertainty. As a second objective, the course aims to introduce some main software tools (Matlab / Simulink, ROS, Gazebo) for the simulation, implementation and verification of applications with mobile and distributed robots.
TEACHING METHODS	Project and presentation. The project consists of an in-depth study of the topics covered in class. The presentation tends to ascertain expressive skills and correct use of technical jargon related to robotic systems,
SUGGESTED BIBLIOGRAPHY	* Dispense fornite dal docente / Lecture notes of the teacher

SYLLABUS

Hrs	Frontal teaching
4	L1 "Introduction to mobile robotics". Industrial and service applications. Nonlinear state forms. Equilibrium stability by Lyapunov theory (recalls to Lyapunov, Barbashin-Krasowskii, Krasovskii-Lasalle theorems).
6	L2 "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	L3 "Distributed Robots". Recalls on graph theory. Message-based cooperation. The linear consensus algorithm. Coordination for rendez-vous, coverage, and formation control. Voronoi partitions.
4	L4 "Racing Vehicles". Wheel and tire mechanics. Tire slippage. Magic formula. Vehicle model (kinematics, road-tire interaction, load transfer, suspension model). Nonlinear single-track model. Longitudinal and lateral control with wind. Hints at dual-track model and MPC control. Optimal planning (at minimum length, curvature or combination).
4	L5 "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.
7	L6 "Advanced nonlinear analysis and control". Reachability and observability, Lie derivative and product, involutive distributions. MIMO exact input-output linearization. Adaptive control and online parameter estimation.
7	L7 "Robots with embodied intelligence". Modeling of articulated soft robots with pneumatic/electric actuation and in agonist-antagonist configuration. Robust and adaptive control of soft robots. Joint stiffness estimation with actuation-side and link-side approaches. Hints at Cartesian stiffness estimation.

Hrs	Practice
4	E1 Simulations in Matlab/Simulink of nonlinear controllers for wheeled robots.
12	E2 "ROS (Robot Operating System)". Architecture and communication protocols. URDF. Programming of ROS nodes in C++. Gazebo Simulator. Realization and verification of controllers in ROS/Gazebo for single and multi-robot systems.