UNIVERSITÀ DEGLI STUDI DI PALERMO

DEPARTMENT	Ingegneria
ACADEMIC YEAR	2018/2019
BACHELOR'S DEGREE (BSC)	INGEGNERIA CIBERNETICA
SUBJECT	PRINCIPLES OF ROBOTICS
TYPE OF EDUCATIONAL ACTIVITY	B
AMBIT	50285-Ingegneria dell'automazione
CODE	19177
SCIENTIFIC SECTOR(S)	ING-INF/04
HEAD PROFESSOR(S)	FAGIOLINI ADRIANO Professore Associato Univ. di PALERMO
OTHER PROFESSOR(S)	
CREDITS	9
INDIVIDUAL STUDY (Hrs)	153
COURSE ACTIVITY (Hrs)	72
PROPAEDEUTICAL SUBJECTS	
MUTUALIZATION	
YEAR	3
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	- Knowledge and Understanding The course is mainly oriented to students of a bachelor laurea degree in cybernetics engineering. Student will learn how to abstract and model physical systems with nonlinear and distributed systems composed of interacting subcomponents. Students will also learn how to study the stability properties of different equilibria of a nonlinear dynamical system; - Applied Knowledge and Understanding Students will be able to identify relations and kinematic constraints among state variables of a nonlinear system, and will learn the methodologies for a correct description of the underlying nonlinear dynamic model. Students will be understand how to apply theoretical analysis tools to prove the validity of motion control algorithms, allowing robots to move in structured and unstructured environments, environments with obstacles, and to cooperatively move in formation; - Independent Judgement Based on the specific application domain in which the robotic mobile platform is required, students will be capable of identifying the essential features and the system requirements, and will know how to autonomously assess the system validity; - Communication Skill Students will be able collaborate will colleagues of the same course, of other bachelor course, and to final users of mobile robots. They will be able to clearly and concisely explain the requirements, the issues, and the advantages of using a mobile robot, notwithstanding the multidisciplinary nature of the topics; - Learning Skill The course will allow students to study essential and advanced properties of existing mobile robots through a formal systematic approach. This will allow in the future students to solve similar problems, even with other control algorithms for vehicles that have not been treated during the course.
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. Such an assessment is generally obtained after 3 questions of different complexity that can spread on the entire course programme. The evaluation is based on the following criteria: a) excellent (30 - 30 with laude): excellent knowledge of the topics, outstanding ability in technical gergo use, analysis ability, the student is able to apply the knowledge in order to solve the presented problems; b) very good (26 - 29): good understanding of the topics, full ability in technical gergo use, the student is able to apply the knowledge in order to solve the presented problems; c) good (24 - 25): basic knowledge of major topics, more than sufficient ability in technical gergo use, sufficient ability to autonomously apply the knowledge in order to solve the presented problems; d) more than sufficient (21 - 23): partial basic knowledge of major topics, sufficient ability in technical gergo use, barely sufficient ability to autonomously apply the knowledge in order to solve the presented problems; e) sufficient (18 - 20): sufficient knowledge of basic topics, barely sufficient ability to autonomously apply the knowledge; f) not sufficient: the student does not show enough knowledge even of basic major topics.
EDUCATIONAL OBJECTIVES	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. The objective is obtained first by considering the nonlinear mathematical models, the theoretical analysis and control tools, and some of the basic techniques for the control of such systems. Secondly, these tools are applied to the study of the dynamic behavior of major mobile robotic platforms, nowadays used, and to the control of underactuated and non-holonomic systems. Finally, by describing procedures and methodologies for trajectory planning, the course will present systems for the exploitation of mobile robots in structured and unstructured environments.
TEACHING METHODS	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.
SUGGESTED BIBLIOGRAPHY	• Dispense fornite dal docente • 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
6	Introduction to Robotics. Applications in the Industry and for Services. Locomotion systems. Odometry based on proprioceptive and exteroceptive sensors. Autonomous navigation in known and unknown, structured and unstructured environments. Multi-robot cooperation. Safe human-robot interaction.
10	Analysis of Nonlinear Dynamic Systems. State forms. Equilibria. Asymptotic stability. Direct and indirect Lyapunov's methods. Quadratic functions and sign definiteness. Speed of convergence. Local and global asymptotic stability (radially bounded functions, Babarshin-Krasovskii's Theorem). Variable Gradient Method. Maximum Invariant Set and Krasovskii-Lasalle's Theorem. Limit Cycles.
12	Wheeled Robots. Non-holomic 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 on line segments or curves with constant curvature).
10	Robot kinematics, rotation matrix, rotation matrix composition, Euler angle, angle/axis representation, homogeneous transformation, direct kinematics, typical robotic structure kinematics determination, joint space and operational space, kinematical calibration, inverse kinematics
10	Differential kinematics, geometric Jacobian matrics, typical manipulator structur jacobian matrix, kinematical singularity, redundance analisys, differential inematics inversion, analitical Jacobian matrix, inverse kinematics algorithm, contact-force / joint-torque correspondence, manipolability ellipsoid.

Hrs	Practice
6	Stability analysis of equilibrium points for second and third order systems, using direct and indirect Lyapunov's method as well as the variable gradient method.
6	Stability and control of inverted pendulum.
4	Stability and control of wheeled robots based on kinematic models
5	Practice exercises on direct kinematics and inverse kinematics
3	Practice on differential kinematics.