UNIVERSITÀ DI PAVIA

Anno Accademico 2021/2022

ADVANCED AUTOMATION AND CONTROL

Enrollment year	2021/2022
Academic year	2021/2022
Regulations	DM270
Academic discipline	ING-INF/04 (AUTOMATICS)
Department	DEPARTMENT OF ELECTRICAL,COMPUTER AND BIOMEDICAL ENGINEERING
Course	COMPUTER ENGINEERING
Curriculum	Embedded and Control Systems
Year of study	1°
Period	1st semester (27/09/2021 - 21/01/2022)
ECTS	9
Lesson hours	84 lesson hours
Language	English
Activity type	WRITTEN TEST
Teacher	FERRARA ANTONELLA (titolare) - 3 ECTS KHALIL HASSAN KAMAL - 1 ECTS RAIMONDO DAVIDE MARTINO - 4 ECTS RAIMONDO DAVIDE MARTINO - 1 ECTS
Prerequisites	Basic knowledge on algorithms. System and control theory for linear systems.
Learning outcomes	The course is structured into two modules: Industrial Automation and Nonlinear Systems. The goal of the Industrial Automation module is to let students familiarize with basic techniques for process planning and management. In particular, methods and algorithms of management science for modelling and solving complex decision problems will be presented. The goal of the Nonlinear Systems module is to discuss methods for the analysis of nonlinear systems using tools from system and control theory. Theory will be illustrated by means of examples from, e.g., mechanical engineering, electrical engineering and aeronautics. In

addition, techniques for the synthesis of feedback regulators for nonlinear systems will be introduced.

Course contents

Industrial Automation module

AUTOMATION OF PRODUCTION PROCESSES. Modelling of production processes. Flexible production systems. Management science. Operations research for decision problems.

MATHEMATICAL PROGRAMMING FOR DECISION PROBLEMS. Modelling of decision problems: variables, cost and constraints. Basics of convex programming. Examples of decision problems including product mix, resource allocation, transport and portfolio selection problems.

LINEAR PROGRAMMING (LP) PROBLEMS. Geometry of LP. Fundamental theorem of LP. Algorithms for LP problems.

Dual Programming.

Multi-parametric Programming.

The simplex method: phase 1 and 2. Tableau form of the simplex method.
Interior Point method.

Sensitivity analysis.

MIXED-INTEGER LINEAR PROGRAMMING (MILP). The use of binary variables in optimization programs. Branch and bound algorithm. Extension also to the case of integer variables (and not only binary)

OPTIMIZATION PROBLEMS ON GRAPHS. Basics of computational complexity theory. Shortest spanning tree problem: Kruskal's algorithm. Shortest path problem: Dijkstra's and Floyd-Warshall algorithms. Flow networks: maximum flow problems and Ford-Fulkerson algorithm.

Dynamic programming: Bellman principle, cost-to-go and Bellman iterations. Application of dynamic programming to optimal control of finite state machines and shortest path problems.

Dynamic programming applied to mobile robotics.

Nonlinear Systems module

INTRODUCTION TO NONLINEAR PHENOMENA. Multiple equilibria, limit cycles, complex dynamics and chaos. Existence and uniqueness of state trajectories.

ANALYSIS OF SECOND-ORDER SYSTEMS. The phase plane: classification of equilibria. Lymit cycles and Poincaré-Bendixon theorem.

	STABILITY THEORY. Lyapunov functions: theorems for checking stability and instability of equilibria. Global stability analysis. LaSalle theorems. Stability for time-varying systems. NONLINEAR CONTROL. Methods based on Lyapunov functions. Backstepping techniques. Sliding Mode Control.
Teaching methods	Lectures (hours/year in lecture theatre): 62 Practical class (hours/year in lecture theatre): 6 Practicals / Workshops (hours/year in lecture theatre): 6
Reccomended or required readings	Recommended textbooks for Industrial Automation (IA) and Nonlinear Systems (NL) modules W. L. Winston, M. Venkataramanan. Introduction to Mathematical Programming: Applications and Algorithm. 4th ed., Duxbury Press, 2002. (IA). C. Vercellis. Ottimizzazione: Teoria, metodi, applicazioni. McGraw-Hill, 2008. (IA - in Italian). A. Ferrara, M. Cucuzzella, G. P. Incremona, Advanced and Optimization Based Sliding Mode Control: Theory and Application, Series: Advances in Design and Control, SIAM, 2019 (NL). H.K. Khalil. Nonlinear systems - third edition. Prentice-Hall, 2002. (NL). S. Sastry. Nonlinear systems - Analysis, Stability and Control. Springer-Verlag, 1999. (NL).
Assessment methods	Closed-book, closed-note written exam. Both knowledge of theory and skills in solving simple exercises will be tested.
Further information	Closed-book, closed-note written exam. Both knowledge of theory and skills in solving simple exercises will be tested.
Sustainable development goals - Agenda 2030	$lbl_legenda_sviluppo_sostenibile