COMPUTER ENGINEERING (LM55)

(Lecce - Università degli Studi)

Teaching ADVANCED CONTROL TECHNIQUES

GenCod A005790

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Teaching in italian ADVANCED CONTROL TECHNIQUES

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SSD code ING-INF/04

Reference course COMPUTER ENGINEERING

Course type Laurea Magistrale

Credits 9.0

Teaching hours Front activity hours: 81.0

For enrolled in 2020/2021

Taught in 2020/2021

Course year 1

Language ENGLISH

Curriculum PERCORSO COMUNE

Location Lecce

Semester Second Semester

Exam type Oral

Assessment Final grade

Course timetable https://easyroom.unisalento.it/Orario

BRIEF COURSE DESCRIPTION

This course offers a broad overview of fundamental and emerging topics in the area of control and systems theory. Applications are illustrated in the fields of robotics, multi-agent systems and cyber-physical systems. It is aimed at providing principles and tools to state and solve optimal control problems eventually seeking distributed control architectures in several technological systems, and the solution is sought both analitically through direct computation and also numerically with the aid of a suitable software (Mathworks Matlab is used in the course).

REQUIREMENTS

Sufficiency in calculus, linear algebra, systems and signals, systems theory.

COURSE AIMS

Learning Outcomes; after the course the student should be able to:

(**Conoscenze e comprensione**) Describe and explain the main peculiarities (both advantages and disadvantages) of the classical and modern control theory considered in the course.

(**Capacità di applicare conoscenze e comprensione**)+ (**Abilità comunicative) + (Autonomia di giudizio)** Be aware of, describe and explain practical problems of controlling complex systems, and how to overcome these drawbacks using modern approaches.

(**Capacità di applicare conoscenze e comprensione**)+ (**Capacità di apprendimento)** For a given practical problem at hand, the student should be able to state a control problem in a natural mathematical setting, eventually seeking distributed architectures, based on the problem assumptions.

(**Capacità di applicare conoscenze e comprensione**) +(**Abilità comunicative) + (Autonomia di giudizio)** Starting from a theoretical formulation of a problem, the student should be able to build a simulation framework to find a computer-aided solution of the stated mathematical problem with the use of a suitable software.

(**Abilità comunicative)+**(**Capacità di apprendimento)** Willing students may develop a project on an application of interest where to apply the methodologies developed along the course.

TEACHING METHODOLOGY

Lezioni frontali svolte in aula dal docente tramite l'ausilio di gesso e lavagna. Nel corso delle lezioni saranno occasionalmente illustrati e discussi software commerciali.

ASSESSMENT TYPE	The exam is a written exam and an oral discussion, and it is aimed to determine to what extent the student has: 1) the ability to identify and use data to formulate responses to well-defined problems, 2) problem solving abilities to seek an analytical solution. Additionally, willing students may have a seminar or a project on an application of interest where the methodologies of the course are applied.
FULL SYLLABUS	Introduction. Mathematical background and connections with other courses (2 hours). Background on Systems theory and linear algebra. Jordan form of a matrix. Linear systems, unforced response and forced response. Exponential and raise to a power of a square matrix. Stability of a linear system and Lyapunov Equation. (10 hours). Linear systems controllability and observability. Eigenvalues placement through state feedback: Rosenbrock theorem. Kalman decomposition of a linear system (7 hours). Introduction to optimal control. Extremum seeking techniques. Functionals. Normed vector spaces. Weak and strong extremum. Differentiable functionals and first variation. (7 hours) Calculus of variations, Euler equation: derivation, comments, examples (10 hours). The Bellman's optimal principle: statement, examples. Cost to go. Costate variables. The optimal control problem solved using the Bellman approach for continuous time systems: HJB equation. Derivation. Examples. (10 hours). The optimal control problem in the presence of saturation: the Pontryagin's maximum principle (6 hours). The linear quadratic optimal control problem. Statement and solution using the variational approach. (6 hours). Discussion on the issues of extending the horizon to infinity. Main theorems. Riccati and Lyapunov equations. Nonsingular solutions of the Riccati Equation. (8 hours). Multi agent systems: an introduction. Examples, main definitions. Centralized architectures vs decentralized ones. Supervisory control, distributed control. (4 hours).Some notions of Graph theory. Dynamical systems over graphs. (7 hours). The importance of consensus in various emerging fields. Consensus protocols. Consensus networks. Analysis of consensus within a multi-agent dynamical system. (6 hours). Consensus problems for directed graphs. Leader-follower multi-agent systems. Symmetries and equitable partitions (3 hours). Directed weighted graphs: a model for consensus networks and cyber-physical systems. Analysis, properties. Differences between directed weighted graphs and undirected weighted graphs. Examples (7 hours). Misbehaving nodes and intruders in a collaborative network . System zeros and output-nulling inputs. Rosenbrock's system matrix. Unobservable zeros and transmission zeros. (5 hours).
REFERENCE TEXT BOOKS	[1] Antsaklis, P. J., & Michel, A. N. (2006). *Linear systems*. Springer Science & Business Media. [2] Anderson, Brian DO, and John B. Moore, *Optimal control: linear quadratic methods*, Courier Corporation, 2007. [3] Bullo, F. *Lectures on Network Systems*, with contributions by J. Cortes, F. Dorfler and S. Martinez, Kindle Direct Publishing, 2018.