MECHATRONICS AND VIBRATIONS

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PROGRAM

In the course program, the dynamics of EMS-Electromechanical Systems and their control are analyzed in details, including systems of rigid bodies and of continuous elastic structures (rod, beam and plates). Applications to vibration analysis and their control, smart structures and mechatronic systems, are examples approached in the course. In details:

1. Introduction to Mechatronics

Architecture of a mechatronic system

Defining the KPIs

Process, sensors, motors / actuators, controllers

Models and sensors measurements

Control of mechatronic systems

2. Multiphysics and Hamilton's Principle

Variational calculus

Minimum principles in Mechanics and Electromagnetism

Theory of EMS- ElectroMechanical System

Hamilton action, the Euler-Lagrange equations

Lagrange equations for electromechanical systems

Linear and nonlinear dynamical systems

3. Linear Dynamics: discrete and continuous systems

Systems of rigid bodies

Systems of continuous elastic structures

Constraints and the method of Lagrange's multiplers

Linearization

Time and Frequency domains: concvolution integral and transfer function

Elements of spectral theory of linear operators

Modal Analysis

Systems with Ndof: Eigenvectors and Eigenfrequencies and their properties

Continuous elastic systems: Eigenfunctions and Eigenfrequencies and their properties

Forced deterministic problems (harmonic, periodic, shock)

Forced random problems (random noise and power spectral density)

Vibrations of elastic and electro-elastic systems

Vibration active, semi-active and passive control

*Applications of Matlab and Simulink for the analysis of oscillating EMS and mechatronics systems

4. Mechatronic Optimal Control

Objective functions

Minimum/minimum of objective functionals

Pontryagin equations

Model predictive control - MPC

Quadratic objective functions and linear dynamics -LQR

General solution by the RIccati's equation

Special solution by Modal Analysis, eigenvector and eigenfrequencies

Models and sensors measurements

Kalman filter

*Applications of Matlab and Smulink to controlled Mechatronics systems

5. Elements of Signal Analysis for Mechatronics and case-studies

Data processing for intelligent control

Extraction of information from data sensors

Sensors and signals

Free response of 1 DOF linear

Forced response of 1 DOF linear

Fourier transform (FT)

Case study 1: Modeling the vibrations of a mechanical resonators subject to different inputs

Case study 2. Modelling and analysis of an open-loop permanent magnet motor coupled with permanent magnet generator in transient and steady-state conditions

Short Time Fourier Transform (STFT)

Power Spectral Density (PSD)

Hilbert Transform, istantaneous frequency and phase (HT and IF)

Empirical mode decomposition (EMD)

Case study 3: The intelligent tyre

Case study 4: Real-time train railways monitoring

Case study 5: Structural damage detection

*Applications of Matlab and Simulink for the analysis of the case-studies

6. Design of Mechatronic Systems

Architecture of a mechatronic system

Defining KPIs

Process, sensors, motors / actuators, controllers

Preliminary design architecture

Designing of the subcomponents (plant, sensors, controller, motors / actuators)

Design of controllers with optimal control methods

Design verification using Simulink

Design examples: electronically controlled intelligent suspension system for motor vehicles, attitude stabilization systems of a drone. Experience in the laboratory of Mechatronics and Vehicles System Dynamics

Type of learning: traditional

The course is based on classroom lectures in which all the theoretical topics are presented. The course is equipped with lessons for the development of exercises based also on the use of computers

Evaluation method

The evaluation modality is based on the execution of a written and an oral test in which the student is requested to examine the model of a mechatronic system, learn to build a block diagram, learn how to carry out the computer simulation.

References

1.) Micromechatronics: Modeling, Analysis, and Design with MATLAB, Second Edition, Victor Giurgiutiu, Sergey Edward Lyshevski, 2009 by CRC Press.
2.) "Vehicle System Dynamics and Mechatronics", A. Carcaterra, Chapter IV "Elements of Control", Sapienza Università Editrice, 2018
3.) Fundamentals of Vibration, L.Meirovitch, McGraw-Hill, 2001
4.) Appunti di Meccanica delle Vibrazioni, A. Carcaterra, 2004
5.) Appunti di Meccanica delle Vibrazioni, A. Sestieri, 1995
6.) Notes on Signal Analysis, N. Roveri, 2016