2021-2022	Mechanical Engineering	Year 4 - Sem. 8
ELEC 431	**Digital and Non-Linear Control**	Mandatory
ECTS: **3**	*Coordinator:* Pr Hassan Shraim	*Language:* English/French
Total hours: **39 h**	*Lectures:* Pr Hassan Shraim, Dr Adel Hallak, Dr Karim Youssef.	

Description:

Properties of physical nonlinear systems. Classification of the non linearities: – single valued, multi-valued, explicit and implicit non linearities, static and dynamic non linearities. Linearization, phase plane method, singular points, construction of phase trajectories using method of isoclines, delta and lineards construction. Lyapunov stability theorem. Digital control system – Introduction to the Z transform, properties of Z transform, the inverse Z transform, Z transform method for solving difference equation. Sampling theorem. Design of digital control system by conventional methods: - mapping between S plane and the Z plane, stability analysis of the close loop system in Z plane, transient and steady state analysis. Design based on the Root locus method; design based on the frequency response method.

Learning outcomes:

- The students will learn how to analyze the properties of the nonlinear systems.
- The student will learn how stabilize a nonlinear system based on several techniques.
- The student will learn how to design nonlinear feedback controllers.
- The student will learn how to analyze, to design, and to implement digital controllers. Emphasize will be given to real-time control of mechatronic systems.

Content:

- Introduction: State-space representation of nonlinear systems, Basic characteristics of nonlinear systems.
- Phase Plane Analysis: Singular points, Construction of phase portraits, methods of isoclines, Phase plane analysis of linear systems, Phase plane analysis of nonlinear systems, Existence of limit cycles.
- Describing Functions Stability analysis and limit cycles: Linear compensation methods, General describing functions of common nonlinearities, Relative stability.
- Lyapunov's direct method: Stability and instability theorems, Variable gradient method, Stability analysis, Method to select Lyapunov function,
- Nonlinear Control System Design: Adaptive control, Practical examples, MATLAB approach in design
- Introduction to discrete time control system: Principal features of discrete time control system, Signal sampling, quantizing and coding, Data acquisition, conversion and distribution system, Reconstruction of original signal from sampled signal.
- The Z-Transform: Fundamentals of Z-transform, Important properties and theorems of the Z-transform, Z-transform from the convolution integral, Inverse Z-transform, Direct Division, Partial Fraction, Inversion Integral, Z-transform method for solving difference equation.
- Analysis of discrete time control system: S-plane to Z-plane mapping and Vice-versa, Stability analysis of closed loop systems in the Z-plane, Discrete time equivalents of continuous time systems, Discrete time equivalents of analog controllers, Transient and steady state response analysis
- Design and compensation of discrete time control system: Digital filters: structure, implementation, frequency response, applications, Control system controllers: structure, hardware/software features, responses to control signals, use of root locus and frequency domain concepts, Phase lead and phase lag compensator design for discrete time system, PID controller design and selection of parameters for discrete time system.

References:

- H. K. Khalil Nonlinear Systems, Third Edition, Prentice-Hall., 2002
- K. Ogata, "Discrete Time Control Systems", Prentice Hall, Englewood Cliffs, New Jersey.
- Charles L. Phillips, "Digital Control System: Analysis and Design", Prentice Hall, Englewood Cliffs, New Jersey.
- H. J. Marquez, Nonlinear Control Systems: Analysis and Design, John Wiley Interscience, 2003.
- J. J. Slotine and W. Li Applied Nonlinear Control, Prentice-Hall, 1991.
- M. Vidyasagar, Nonlinear Systems Analysis, SIAM, 2002.

Evaluation Method:

Assessment in the following areas will be converted to points, to compute your final grade in this course:

- Mid-Term
- Final Exam
- Home Works

Description :

Les propriétés du système physique non linéaire. Classification des non-linéarités : valeur unique, valeurs multiples, et non-linéarités implicites et explicites, non linéarités statiques et dynamiques. Analyse des systèmes de contrôle non linéaire : linéarisation, méthode de plan de phase, points singuliers, la construction des trajectoires de phase en utilisant la méthode de isoclines, delta et lineards construction. Stabilité par le théorème de Lyapunov. Système de contrôle numérique - Introduction à la transformée en Z, propriétés de transformée en Z, l'inverse transformée en Z, Z méthode pour résoudre l'équation de différence. Théorème d'échantillonnage. Conception d'un système de commande numérique par des méthodes classiques : la cartographie entre le plan S et le plan Z, l'analyse de la stabilité du système en boucle fermée dans le plan Z, l'analyse de la stabilité en régime transitoire et en régime permanant. Conception basée sur la méthode du lieu des racines et sur la méthode de réponse fréquentielle.