SYLLABUS

1. Data about the program of study

1.1 Institution	The Technical University of Cluj-Napoca
1.2 Faculty	Faculty of Automation and Computer Science
1.3 Department	Automation
1.4 Field of study	System's Engineering
1.5 Cycle of study	Master
1.6 Program of study / Qualification	CYBER PHYSICAL SYSTEMS
1.7 Form of education	Full time

2. Data about the subject

2.1 Subject name	***Emerging Control Systems for Industry 5.0***				Subject code	**16.10**
2.2 Course responsible / lecturer	Sl. Dr. Ing. Isabela Birs – isabela.birs@aut.uctluj.ro					
2.3 Teachers in charge of seminars / Laboratory / project	Sl. Dr. Ing. Isabela Birs – isabela.birs@aut.uctluj.ro					
2.4 Year of study	2	2.5 Semester	2	2.6 Type of assessment (E - exam, C - colloquium, V – verification)		E
2.7 Subject category	Formative category: DA – advanced, DS – speciality, DC – complementary					DA
	Optionality: DI – imposed, DO – optional (alternative), DF – optional (free choice)					DO

3. Estimated total time

3.1 Number of hours per week	3	of which:	Course	2	Seminars		Laboratory	1	Project	
3.2 Number of hours per semester	42	of which:	Course	28	Seminars		Laboratory	14	Project	

3.3 Individual study:	
(a) Manual, lecture material and notes, bibliography	23
(b) Supplementary study in the library, online and in the field	10
(c) Preparation for seminars/laboratory works, homework, reports, portfolios, essays	10
(d) Tutoring	2
(e) Exams and tests	3
(f) Other activities:	

3.4 Total hours of individual study (suma (3.3(a)…3.3(f)))	58
3.5 Total hours per semester (3.2+3.4)	100
3.6 Number of credit points	4

4. Pre-requisites (where appropriate)

4.1 Curriculum	System Theory I+II, Control Engineering I+II
4.2 Competence	Fundamental knowledge of automation

5. Requirements (where appropriate)

5.1. For the course	Bibliography reading for lectures
5.2. For the applications	Laboratory classes are compulsory

6. Specific competence

6.1 Professional competences	• Interacts professionally in research and professional environments • Applies the principles of scientific ethics and integrity in research activities • Conducts interdisciplinary research • Conducts literature research • Conduct scientific research • Operates scientific and laboratory research equipment • Presents analysis results • Performs data analysis • Writes scientific and academic papers and technical documentation • Develop scientific publications • Synthesizes information
6.2 Cross competences	• Think analytically • Apply scientific, technological, and engineering knowledge

7. Expected Learning Outcomes

Knowledge	The student will know • advanced concepts, principles, and methodologies in systems engineering, automation, and cyber-physical systems • principles of design, operation, and evaluation for complex control systems, industrial networks, and related hardware and software components • modeling and simulation methods for control systems, including how to develop and analyze dynamic models of industrial and cyber-physical systems • interdisciplinary concepts from mathematics, signal processing, automation, control theory, and computer science applicable to the design and optimization of complex systems
Skills	The student will be able to • design, develop, simulate, and implement hardware, software, and control applications for industrial and cyber-physical systems • analyze technical data, evaluate alternatives, and apply problem-solving strategies to complex engineering challenges • integrate multidisciplinary knowledge to design, optimize, implement, and evaluate innovative solutions for complex control systems and industrial networks
Responsibilities and autonomy	• The student will be responsible for carrying out professional or research projects in compliance with quality, safety, and security standard • The student will be responsible for ensuring ethical conduct, academic integrity, and proper management of research and experimental data

8. Discipline objective (as results from the *key competences gained*)

8.1 General objective	Introduction into basic concepts related to fractional order control, autotuning methods and event-based implementations
8.2 Specific objectives	• Industry 5.0 concepts and modernization of control systems • Emerging control methods • Analysis and synthesis of fractional order control strategies • Analysis and synthesis of auto-tuning methods • Event-based implementation possibilities and advantages

9. Contents

9.1 Lectures	Hours	Teaching methods	Notes
Introduction: from Industry 1.0 towards Industry 5.0. Industry 4.0 and cyber physical systems. Industry 5.0 and cyber physical cognitive systems (CPGS). Modern control systems.	4	PPT presentations, open discussions,	In case of major force classes will

Emerging control methods suitable for Industry 5.0. Basics of auto-tuning methods	4	demonstration, case studies	be held online using Teams
Fractional order control systems: introduction, advantages, tuning, implementation	4		
Fractional order control systems and auto-tuning methods. A time domain approach. Implementation and validation on CPGS	4		
Fractional order control systems and auto-tuning methods. A frequency domain approach. Implementation and validation on CPGS	4		
Fractional order event-based control systems. Increasing the efficiency of control systems by reducing energy use according to the sustainability standards sought by Industry 5.0.	4		
Industrialization of fractional order control systems. Case studies	4		

Bibliography:

- Monje, C.A.; Chen, Y.Q.; Vinagre, B.; Xue, D.; Feliu, V. Fractional Order Systems and Controls: Fundamentals and Applications; Springer: Berlin, Germany, 2010
- C. Copot, C.M. Ionescu, C.I. Muresan (2020), Image-Based and Fractional-Order Control for Mechatronic Systems. Theory and Applications with MATLAB®, ISBN 978-3-03-042005-5, 978-3-03-042006-2, DOI: 10.1007/978-3-030-42006-2, Springer
- Cristina I. Muresan, Robin De Keyser, Revisiting Ziegler–Nichols. A fractional order approach, ISA Transactions, 2022,DOI: 10.1016/j.isatra.2022.01.017
- I. Birs, I. Nascu, C. Ionescu, C. Muresan (2020), “Event-based fractional order PID control”, Journal of Advanced Research, Volume 25, pp.191-203, DOI: 10.1016/j.jare.2020.06.024 BURNS Roland S., Advanced control engineering, 2004, Oxford
- Vilanova, Ramón and Antonio Visioli. “PID control in the Third Millennium: lessons learned and new approaches.” (2012).

9.2 Applications - Seminars/Laboratory/Project	Hours	Teaching methods	Notes
Introduction into Industry 5.0 and analysis of modern control systems	2		
Implementation of standard auto-tuning methods. Case study: vertical take-off and landing	2		
Analysis and implementation of fractional order control systems using various software tools (FOMCOM, NINTEGER, AFOPI, FLOreS). Matlab simulation.	2		
Practical implementation and validation of fractional order control systems. Case study: vertical take-off and landing.	2		
Practical implementation and validation of fractional order control systems and auto-tuning methods. Case study: DC motor control.	2		
Practical implementation and validation of fractional order control systems and auto-tuning methods. Case study: vertical take-off and landing platform.	2		
Event-based implementation of fractional order controllers. Case study: vertical take-off and landing platform.	2		

Bibliography

- Tepljakov, Aleksei, et al. “FOMCON Toolbox for Modeling, Design and Implementation of Fractional-Order Control Systems.” Applications in Control, De Gruyter, 2019, pp. 211–36, doi:10.1515/9783110571745-010.
- Lennart van Duist, Gijs van der Gugten, Daan Toten, Niranjan Saikumar, Hassan HosseinNia, FLOreS - Fractional order loop shaping MATLAB toolbox, IFAC-PapersOnLine, Volume 51, Issue 4, 2018,Pages 545-550, DOI: 10.1016/j.ifacol.2018.06.152.
- QNET 2.0 VTOL Board for NI ELVIS, Student workbook, Quanser, Ontario, Canada, 2011
- https://www.mathworks.com

Se vor preciza, după caz: tematica seminariilor, lucrările de laborator, tematica și etapele proiectului.

9. Bridging course contents with the expectations of the representatives of the community, professional associations and employers in the field

The content of the lectures and laboratory classes corresponds to some of the newest approaches in control engineering. Selected case studies refer to emerging applications, ranging from aerodynamics to biomedical engineering. The content of the lectures and the laboratory classes has been discussed with companies in Romania.

10. Evaluation

Activity type	Assessment criteria	Assessment methods	Weight in the final grade
Course	Evaluation of the acquired skills, activity within lectures	Written exam (research project)	50%
Seminar	-		
Laboratory	Evaluation of the practical skills, attendance, activity within laboratory classes	Oral exam	50%
Project	-		
Minimum standard of performance: Exam grade >5, Laboratory grade>5			

Date of filling in: 05.07.2026	**Responsible**	**Title First name Last name**	**Signature**
	Course	SL. Dr. Ing. Isabela Birs	
	Applications	SL. Dr. Ing. Isabela Birs	

Date of approval in the department of Automation __________________________	Head of department, Prof.dr.eng. Honoriu VĂLEAN
Date of approval in the Faculty of Automation and Computer Science Council ___________________________	Dean, Prof.dr.eng. Vlad MUREȘAN