# SYLLABUS

## 1. Data about the program of study

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|---|---|---|
| 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 | Systems Engineering |
| 1.5 | Cycle of study | Research Masters |
| 1.6 | Program of study/Qualification | CYBER PHYSICAL SYSTEMS |
| 1.7 | Form of education | Full time |
| 1.8 | Subject code | 16.10 |

## 2. Data about the subject

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|---|---|---|---|---|---|---|---|
| 2.1 | Subject name | | | Emerging Control Systems for Industry 5.0 | | | |
| 2.2 | Subject area | | | Systems Engineering | | | |
| 2.2 | Course responsible/lecturer | | | Prof.Dr.Ing. Cristina I. Muresan<br>cristina.muresan@aut.utcluj.ro | | | |
| 2.3 | Teachers in charge of seminars | | | Prof.Dr.Ing. Cristina I. Muresan<br>cristina.muresan@aut.utcluj.ro | | | |
| 2.4 Year of study | 2 | 2.5 Semester | 2 | 2.6 Assessment | E | | |
| 2.7 Subject category | Formative category | | | | | | DA |
| | Optionality | | | | | | DO |

## 3. Estimated total time

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 3.1 Number of hours per week | 3 | of which | 3.2 Course | 2 | 3.3 Seminar | | 3.3 Laborator | 1 | 3.3 Proiect | 0 |
| 3.4 Total hours in the curriculum | 42 | of which | 3.5 Course | 28 | 3.6 Seminar | | 3.6 Laborator | 14 | 3.6 Proiect | 0 |

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|---|---|
| 3.7 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 | 20 |
| (d) Tutoring | 2 |
| (e) Exams and tests | 3 |
| (f) Other activities | 0 |

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|---|---|
| 3.8 Total hours of individual study (summ (3.7(a)…3.7(f))) | 58 |
| 3.9 Total hours per semester (3.4+3.8) | 100 |
| 3.10 Number of credit points | 4 |

## 4. Pre-requisites (where appropriate)

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

## 5. Requirements (where appropriate)

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|---|---|---|
| 5.1 | For the course | Bibliography reading for lectures |
| 5.2 | For the applications seminarului / laboratorului / proiectului | Laboratory classes are compulsory |

**6. Specific competences**

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|---|---|
| Professional competences | C4. Analysis, synthesis and implementation of advanced control startegies with practical applications<br>C4.1 Performance criteria for advanced process control methods<br>C4.2 Use of interdisciplinary and multidisciplinary knowledge and information to integrate advanced process control methods in an industrial setting<br>C4.3 Creative use of principles and advanced methods to ensure safety, security and employment of advanced process control methods<br>C4.5 Development of professional or/and interdisciplinary research projects, while meeting quality, security and safety standards |
| Cross competences | Team work<br>Scientific communication of results |

**7. Discipline objectives (as results from the *key competences gained*)**

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|---|---|---|
| 7.1 | General objective | • Introduction into basic concepts related to fractional order control, autotuning methods and event-based implementations |
| 7.2 | Specific objectives | • Industry 5.0 concepts and modernization of control systems<br>• Emerging control methods<br>• Analysis and synthesis of fractional order control strategies<br>• Analysis and synthesis of auto-tuning methods<br>• Event-based implementation possibilities and advantages |

**8. Contents**

| 8.1. Lecture (syllabus) | Number of 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, demonstration, case studies | In case of major force classes will be held online using Teams |
| Emerging control methods suitable for Industry 5.0. Basics of auto-tuning methods | 4 | | |

| | | | |
|---|---|---|---|
| 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


1. Monje, C.A.; Chen, Y.Q.; Vinagre, B.; Xue, D.; Feliu, V. Fractional Order Systems and Controls: Fundamentals and Applications; Springer: Berlin, Germany, 2010
2. 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
3. Cristina I. Muresan, Robin De Keyser, Revisiting Ziegler–Nichols. A fractional order approach, ISA Transactions, 2022,DOI: 10.1016/j.isatra.2022.01.017
4. 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
5. Vilanova, Ramón and Antonio Visioli. "PID control in the Third Millennium: lessons learned and new approaches." (2012).


| 8.2. Seminars /Laboratory/Project | Number of hours | Teaching methods | Notes |
|---|---|---|---|
| Introduction into Industry 5.0 and analysis of modern control systems | 2 | Practical use of dedicated equipment, case studies, demonstration, brainstorming | In case of major force classes will be held online using Teams |
| 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. Case study: anesthesia control | 2 | | |
| Practical implementation and validation of fractional order control systems. Case study: vertical take-off and landing. | 2 | | |

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|---|---|---|---|
| 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


1. 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.
2. 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.
3. QNET 2.0 VTOL Board for NI ELVIS, Student workbook, Quanser, Ontario, Canada, 2011
4. https://www.mathworks.com


**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 | 10.1 Assessment criteria | 10.2 Assessment methods | 10.3 Weight in the final grade |
|---|---|---|---|
| 10.4 Course | Evaluation of the acquired skills, activity within lectures | Written exam | 50% |
| 10.5 Seminars /Laboratory/Project | Evaluation of the practical skills, attendance, activity within laboratory classes | Oral exam | 50% |
| 10.6 Minimum standard of performance Exam grade >5, Laboratory grade>5 | | | |
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| Date of filling in: | | Title Surname Name | Signature |
| --- | --- | --- | --- |
| 16.03.2023 | Lecturer | Prof. dr.ing. Cristina I. Muresan | |
| | Teachers in charge of application | Prof. dr.ing. Cristina I. Muresan | |
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| Date of approval in the Department of Automation<br><br>______________________ | Head of department<br>Prof.dr.ing. Honoriu Valean |
| Date of approval in the Faculty of Automation and Computer Science<br><br>____________________ | Dean<br>Prof.dr.ing. Liviu Miclea |