# Syllabus

**1. Data about the program of study**

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| 1.1 Institution | Technical University of Cluj-Napoca |
| 1.2 Faculty | Automation and Computer Science |
| 1.3 Department | Automation |
| 1.4 Field of study | Systems Engineering |
| 1.5 Cycle of study | Bachelor of Science |
| 1.6 Program of study/Qualification | Automation and Applied Informatics (English) |
| 1.7 Form of education | Full time |
| 1.8 Code | 56.10 |

**2. Data about the subject**

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|---|---|---|---|---|---|
| 2.1 Subject name | Estimators in control of dynamic systems | | | | |
| 2.2 Course responsible/lecturer | Zsófia Lendek, Zsofia.lendek@aut.utcluj.ro | | | | |
| 2.3 Teachers in charge of applications | Zsófia Lendek, Zsofia.lendek@aut.utcluj.ro | | | | |
| 2.4 Year of study | 4 | 2.5 Semester | 2 | 2.6 Assessment *(E/C/V)* | C |
| 2.7 Type of subject | *DF – fundamental, DID – in the field, DS – specialty, DC – complementary* | | | | DS |
| | *DOB – compulsory, DOP – elective, FAC – optional* | | | | DO |

**3. Estimated total time**

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|---|---|---|---|---|---|---|---|---|---|---|
| 3.1 Number of hours per week | 4 | of which: | Course | 2 | Seminar | | Laboratory | | Project | 1 |
| 3.2 Number of hours per semester | 42 | of which: | course | 28 | Seminar | | Laboratory | | Project | 14 |
| 3.3 Individual study | | | | | | | | | | |
| (a) Manual, lecture material and notes, bibliography | | | | | | | | | | 10 |
| (b) Supplementary study in the library, online and in the field | | | | | | | | | | 20 |
| (c) Preparation for seminars/laboratory works, homework, reports, portfolios, essays | | | | | | | | | | 47 |
| (d) Tutoring | | | | | | | | | | 3 |
| (e) Exams and tests | | | | | | | | | | 3 |
| (f) Other activities: | | | | | | | | | | |

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| 3.4 Total hours of individual study (sum of (3.3(a)…3.3(f))) | 83 |
| 3.5 Total hours per semester (3.2+3.4) | 125 |
| 3.6 Number of credit points | 5 |

**4. Pre-requisites** (where appropriate)

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| 4.1 Curriculum | Numerical calculus, analysis, linear algebra, differential equations, control engineering |
| 4.2 Competence | Numerical calculus, analysis, linear algebra, differential equations, control engineering, Matlab |

**5. Requirements** (where appropriate)

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| 5.1. For the course | Attending at least 7 lectures is compulsory. |
| 5.2. For the applications | Presence and successfully completing the project are compulsory |

**6. Specific competences**

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| 6.1 Professional competences | **C1**<br>Using knowledge of mathematics, physics, mechanical engineering, chemistry, electrical and electronic engineering in systems engineering<br>C3<br>Using basics of control engineering, methods of modeling, simulation, identification and analysis of processes, computer assisted design techniques. |
| 6.2 Cross competences | |

**7. Course objectives**

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| 7.1 General objective | - Estimation problems in control engineering<br>- Design of commonly used observers |
| 7.2 Specific objectives | - Formulating an estimation problem<br>- Observability analysis<br>- Methods used for state estimation for a linear system |

**8. Contents**

| 8.1 Lecture | No.hours | Teaching methods | Notes |
|---|---|---|---|
| Introduction. State-space description of dynamical systems. Formulating an estimation problem. Soft sensors. Case studies: electromechanical systems, 3D crane, inverted pendulum, robotic manipulators, quadcopters. | 6 | Exposition<br>Questions<br>Discussions with students<br>Proofs | Possibly online on Teams |
| Observers for linear systems. Luenberger observers in discrete and continuous time. Convergence of the estimated values to the real ones. Limitations. Case studies: experiments from the Rotary package (Quanser). | 4 | | |
| Linear regression. Least squares methods. The effect of noise. Case study: 3D crane. | 2 | | |
| Noises and disturbances. Kalman filters in continuous and discrete time. Analysis. Estimation with bounded inputs and states. Prediction and smoothing. Limitations. Case studies: sensor fusion for mobile robots. | 6 | | |
| Sensor and actuator faults. Fault detection. Case studies: electromechanical systems. | 4 | | |
| Observers design for control. The separation principle. Case studies: robotic systems. | 6 | | |
| Bibliography<br>1.Beyond the Kalman filter : particle filters for tracking applications, Branko Ristic, Sanjeev Arulampalam, Neil Gordon, Artech House, 2003<br>2.Modern control design : with MATLAB and SIMULINK, Ashish Tewari, Wiley, 2002<br>3.Stability analysis and nonlinear observer design using Takagi-Sugeno fuzzy models, Zsofia Lendek, Thierry Marie Guerra, Robert Babuska, Bart De Schutter, Springer, 2011<br>4.Optimal State Estimation: Kalman, H-infinity, and Nonlinear Approaches, Dan Simon, Wiley, 2006<br>5. Lecture notes available online at lendek.net/teaching | | | |

| 8.2 Aplications (seminar/laboratory/project) | No.hours | Teaching methods | Notes |
|---|---|---|---|
| State-space representation of linear systems. Examples. Variables and parameters that need to be estimated. Applications. | 2 | Implementation and analysis.<br><br>Literature study, implementing methods or applications, report writing | Attendance mandatory. Matlab will be used. Possibly online on Teams |
| Luenberger observers. Applications. | 3 | | |
| Linear regression. Applications. | 2 | | |
| Kalman filters in continuous and discrete time. Prediction and smoothing. Extended Kalman filters. Applications. | 4 | | |
| Sensor and actuator faults. Observer design for fault detection. Applications. | 3 | | |
| Bibliography<br>1.Beyond the Kalman filter : particle filters for tracking applications, Branko Ristic, Sanjeev Arulampalam, Neil Gordon, Artech House, 2003<br>2.Modern control design : with MATLAB and SIMULINK, Ashish Tewari, Wiley, 2002<br>3.Stability analysis and nonlinear observer design using Takagi-Sugeno fuzzy models, Zsofia Lendek, Thierry Marie Guerra, Robert Babuska, Bart De Schutter, Springer, 2011<br>4.Optimal State Estimation: Kalman, H-infinity, and Nonlinear Approaches, Dan Simon, Wiley, 2006<br>5. Lecture notes available online at lendek.net/teaching | | | |

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

Since in general not all variables can be measured, observers need to be employed. The methods taught at this course represent the basis in this subject. Thus, the students will be capable to recognize if an observer is necessary, formulate the estimation problem, to analyse the problem, determine the methods that can be used to solve it and interpret the results.

The knowledge acquired can be applied both in the academic community and in industry (state-feedback control, optimization of industrial processes)

**10. Evaluation**

| Activity type | Assessment criteria | Assessment methods | Weight in the final grade |
|---|---|---|---|
| Course | Level of understanding of the material | Exam | 1 |
| Seminar | | | |
| Laboratory | | | |
| Project | Implementation, analysis, report, discussion | Validation during the semester | |
| Minimum standard of performance: project successfully completed and final grade >=5 | | | |

| **Date of filling in:** 21.03.2023 | | **Title Firstname NAME** | **Signature** |
|---|---|---|---|
| | Course | Prof dr ing Zsófia Lendek | |
| | Aplications | Prof dr ing Zsófia Lendek | |

Date of approval by the Department Board ……..

Head of Departament .....
Prof.dr.ing. Honoriu VĂLEAN

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Date of approval by the Faculty Council ……

Dean
Prof.dr.ing. Liviu Cristian MICLEA

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