COURSE DESCRIPTION CARD - SYLLABUS

Course name

DATA DRIVEN CONTROL SYSTEMS - CONCEPTS, METHODS AND APPLICATIONS

Course

Proposed by Discipline

Automation, electronics, electrical engineering and space technologies

Type of studies

Doctoral School

Form of study

full-time

Year/Semester

II/3

Course offered in

English

Requirements

elective

Number of hours

Lecture	Tutorials	Projects/seminars
8		

Number of credit points

2

Lecturers

Responsible for the course/lecturer:

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Faculty of Control, Robotics, and Electrical Engineering
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Responsible for the course/lecturer:

Prerequisites

Knowledge: Good knowledge of control systems and machine learning methods, Familiarity with linear algebra

Skills: Basic programming skills (Python/Matlab)

Social competencies: recognise the importance of new data-driven methods in the development of control systems theory and practice

Course objectives

1. In-depth understanding of the basic principles of data-driven control systems, including system identification, model-free control strategies and reinforcement learning methods.

2. Gain proficiency in applying advanced data-driven control techniques to real-world problems, using appropriate algorithms and software tools to design, simulate and implement control systems in various fields.

3. Prepare students to remain current in the rapidly evolving field of data-driven control systems, fostering a commitment to continuous learning and professional development.

By the end of this course, students will be equipped with knowledge and skills in the field of data-driven control systems, contributing to both academic research and practical applications in various fields of engineering and technology.

Course-related learning outcomes

Knowledge

A PhD student who graduated from doctoral school knows and understands:

1) current developments in the combined fields of machine learning and control theory, understand the basic principles of creating control systems using reinforcement learning and physics-informed machine learning methods, [P8S_WG/SzD_W02]
2) research methodology for the synthesis and analysis of data-driven control systems, [P8S_WG/SzD_W03]

Skills

A PhD student who graduated from doctoral school can:

1) use methods such as reinforcement learning and other data-based methods for the synthesis of control systems for a variety of objects., [P8S_UW/SzD_U01]
2) critically analyze the results of data driven method application in the design of control systems, [P8S_UW/SzD_U02]
3) plan research project with the application of data driven approach to the synthesis of control systems, [P8S_UK/SzD_U09]

Social competencies

A PhD student who graduated from doctoral school is ready to:

1) recognize the importance of data-driven methods in the design of a variety of control systems, [P8S_KK/SzD_K03]

Methods for verifying learning outcomes and assessment criteria

Learning outcomes presented above are verified as follows:

PQF code	Methods for verification of learning outcomes	Assessment criteria
W02, W03	written test (solving research problem)	assessment of knowledge and skills by the completion of test
U01, U02, U09	written test (solving research problem)	assessment of knowledge and skills by the completion of test
K03	written test (solving research problem)	assessment of knowledge and skills by the completion of test

Programme content

Data-driven control systems are a family of control systems, in which the identification of the process model or the design of the controller are based on experimental data collected from the plant.

The objective of this lecture series is to examine the convergence of data-driven methodologies, machine learning, and the traditional discipline sof control theory and controller design. The data-driven approach is currently changing the way we model, predict, and control complex systems. The focus of this study will be on two specific areas: Reinforcement Learning and Physics-Informed Machine Learning. Reinforcement Learning is a third major branch of machine learning that is concerned with the development of control laws and policies to enable the interaction of machines with complex environments. This is a key area of research, situated at the growing intersection of control theory and machine learning. The integration of physics concepts, constraints, and symmetries is providing exceptional opportunities for the training of machine learning algorithms that are encoded with knowledge of physics.

Course topics

1. Overview of Data-Driven Control Systems: Definition and significance, Comparison with model-based control systems.
2. Supervised Learning in Control Systems: Regression and classification for system modelling, Feature selection and dimensionality reduction, Overfitting, regularization, and model validation.
3. Model-Free Reinforcement Learning: Value-based methods: Q-learning, Policy-based methods: REINFORCE algorithm Actor-critic methods: A3C, DDPG.
4. Model-Based Reinforcement Learning: Introduction to model-based RL, Planning and learning: Dyna-Q, Algorithms and their applications in control systems.

5. Applications in Control Systems: Autonomous vehicles, Robotics, Process control, Energy management systems.
6. Fundamentals of Physics-Informed Machine Learning: Definition and motivation for PIML, Overview of traditional machine learning vs. physics-informed approaches, embedding physical laws into learning algorithms.
7. Applications in Control Systems: Fluid dynamics and control, Energy systems and smart grids.
8. Current Research and Future Directions.

Teaching methods

Lecture: multimedia presentation including illustrations and examples.

Bibliography

Basic

1. Steven L. Brunton and J. Nathan Kutz: Data-Driven Science and Engineering: Machine Learning, Dynamical Systems, and Control.
2. Richard S. Sutton Andrew G. Barto: Reinforcement Learning: An Introduction.
3. Ryan G. McClarren: Machine Learning for Engineers: Using data to solve problems for physical systems.
4. Ali Khaki-Sedigh: An Introduction to Data-Driven Control Systems.

Additional

1. Novara Carlo: Data-Driven Modeling, Filtering and Control: Methods and Applications.
2. Selected research papers and articles (provided during the course).
3. Software: Python with libraries such as TensorFlow, PyTorch, and specialized PIML libraries for hands-on exercises.
4. Software: Matlab with toolboxes for hands-on exercises.

Breakdown of average student's workload

	Hours	ECTS
Total workload	50	2,0
Classes requiring direct contact with the teacher	8	0,0
Doctoral student's own work (literature studies, preparation for tutorials, project preparation) [1]	42	2,0

[1] delete or add other activities as appropriate