Advanced AI Models in Engineering

Course description sheet

Basic information

Field of study Mechatronic Engineering with English as instruction language **Major** Mechatronic Design **Organisational unit** Faculty of Mechanical Engineering and Robotics **Study level** Second-cycle (engineer) programme **Form of study** Full-time studies **Profile** General academic	**Didactic cycle** 2026/2027 **Course code** RIMAMDS.IIi2.18793.26 **Lecture languages** English **Mandatoriness** Elective **Block** Major Modules **Course related to scientific research** No

Course coordinator	Ziemowit Dworakowski
Lecturer	Ziemowit Dworakowski

Period	**Method of verification of the learning outcomes**	**Number of ECTS credits**
Semester 2	Completing the classes **Activities and hours** Lectures: 16 Laboratory classes: 36 Project classes: 18	5

Goals

C1	Equip students to apply advanced AI models to real-world engineering problems using modular and context-aware design approaches.
C2	Develop the ability to work with imperfect, domain-specific data and to select, adapt, and justify appropriate modeling strategies.
C3	Foster independent exploration and critical thinking through guided assignments and project work, preparing students to act as responsible model architects.

Course's learning outcomes

Code	Outcomes in terms of	Learning outcomes prescribed to a field of study	Methods of verification
Knowledge – Student knows and understands:			
W1	the principles and limitations of advanced AI methods, including evolutionary algorithms, deep learning architectures, and hybrid models integrating physical knowledge.	IMA2A_W03, IMA2A_W07	Participation in a discussion, Test, Oral answer
W2	the role of model complexity, data quality, and contextual information in engineering-oriented AI system design.	IMA2A_W02, IMA2A_W07	Participation in a discussion, Test, Oral answer
W3	current strategies for explainable, robust, and trustworthy AI in engineering contexts.	IMA2A_W02, IMA2A_W07	Participation in a discussion, Test, Oral answer
Skills – Student can:			
U1	design and implement AI-based models for real-world engineering problems, selecting appropriate tools and justifying modeling decisions.	IMA2A_U01	Project, Report
U2	evaluate and improve AI systems using structured experimentation, comparative analysis, and critical self-assessment.	IMA2A_U08	Project, Report
U3	document, visualize, and communicate the modeling process, decisions, and results in a way that meets professional and reproducibility standards.	IMA2A_U03, IMA2A_U04, IMA2A_U05	Project, Report, Presentation
Social competences – Student is ready to:			
K1	taking responsibility for methodological choices in AI-based engineering solutions, including the identification and communication of their limitations.	IMA2A_K02, IMA2A_K03	Participation in a discussion, Project, Presentation, Oral answer
K2	observing the ethical, safety-related, and societal implications of AI deployment in engineering applications.	IMA2A_K03	Participation in a discussion, Project, Oral answer
K3	demonstration of initiative in acquiring missing knowledge, seeking feedback, and improving their own solutions.	IMA2A_K01	Participation in a discussion, Project

Program content ensuring the achievement of the learning outcomes prescribed to the module

The course is structured around modular, medium-scale assignments that reflect real-world engineering challenges and require students to explore, adapt, and justify advanced AI models.
Knowledge outcomes are addressed through self study using the provided sources and thematic lecture blocks introducing state-of-the-art methods, real-world modeling contexts, and critical considerations such as explainability, hybrid modeling, and data quality. Skills outcomes are developed through laboratory-based exploration of selected modules, where students implement models, analyze their performance, and iteratively refine their approach based on experimentation and self-study. Social competence outcomes are cultivated through project consultations, oral check-ins, and documentation requirements that emphasize responsible model design, awareness of limitations, and independent knowledge acquisition.

Student workload

Activity form	**Average amount of hours* needed to complete each activity form**
Lectures	16
Laboratory classes	36
Project classes	18
Contact hours	5
Examination or final test/colloquium	1
Realization of independently performed tasks	40
Preparation for classes	13
Preparation of project, presentation, essay, report	12
Student workload	**Hours** 141
Workload involving teacher	**Hours** 70

* hour means 45 minutes

Program content

No.	Program content	Course's learning outcomes	Activities
1.	Lecture topics Course Introduction & Foundational Recap Overview of the course structure, goals, and grading, followed by a refresher on core AI, optimization, control, and signal processing concepts. Modular Thinking and the Role of the Model Architect Introduction to the mindset of system-level design using AI tools, focusing on composability, constraints, and responsible model integration. Advanced optimization solutions Evolutionary optimization, PSO, annealing schemes - how to assess, principles of configuration and pitfalls Messy Data in Engineering Practice A look at real-world data challenges — noise, scarcity, and structure — and how different modeling approaches address these issues. Modeling Complex System Behavior Approaches to handling time-dependence, feedback, and nonlinearity in systems using tools like LSTMs, surrogates, and physics-based models. Design Under Constraints and Multi-Objective Tension Exploration of design strategies in constrained environments, comparing optimization, explainability, and domain-informed modeling trade-offs. Trust, Safety, and Interpretability Discussion of model transparency, reliability, and ethical responsibility across various AI approaches in engineering applications. Integration and Deployment of AI Systems Strategies for embedding AI models into larger engineering workflows, including control loops, diagnostic systems, and simulation pipelines.	W1, W2, W3	Lectures

No.	Program content	Course's learning outcomes	Activities
2.	Student chooses three out of the following six themes to work on in the form of mini-projects and self-organized laboratory assignments: Evolutionary Optimization in Engineering Design Application of evolutionary algorithms to complex, multi-objective engineering problems with simulation-based or experimental evaluation. Physics-Informed and Context-Enriched Modeling Integration of domain knowledge and physical laws into machine learning models to improve generalization and interpretability. Data-Driven Process Modeling and Control Modeling dynamic systems using learning-based approaches (e.g., LSTMs, neural-MPC) for prediction, simulation, or control. Explainable and Trustworthy AI in Engineering Exploration of techniques for improving transparency, robustness, and interpretability of AI models in safety-critical systems. Surrogate Modeling and System Identification Development of fast, approximate models to replace complex simulations or unknown systems using data-driven learning. Learning from Sparse, Noisy, or Imperfect Data Investigation of strategies such as data augmentation, transfer learning, and robustness techniques to handle real-world data limitations.	U1, U2, U3, K1, K2, K3	Laboratory classes, Project classes

Extended information/Additional elements

Teaching methods and techniques :

Lectures, Case study, Group work, Flipped classroom, Problem Based Learning, Project Based Learning, Oxford debate, Feedback, Team Based Learning, Lecture

Activities	Methods of verification	Credit conditions
Lectures	Test	Min. 10 knowledge tokens received
Lab. classes	Participation in a discussion, Report, Oral answer	Min. 15 activity tokens received
Project classes	Project, Report, Presentation, Oral answer	Min. 15 activity tokens received

Additional info

The course grading is organized using a system of tokens divided into knowledge and activity categories. The knowledge tokens are used to determine knowledge-related effects of studying while activity tokens reflect practical problem-solving capabilities in area of advanced AI system design.
For **knowledge tokens** the activities to choose are as follows:
up to 5 tokens: Case study submission and participation in the lecture (15 minute presentation during the lecture) **up to 5 tokens:** Lecture discussion (Individual, at consultations or after the lecture, up to 2 times) **up to 5 tokens**: Lecture participation (1 token per lecture) **up to 15 tokens:** Final merit test - as an additional chance to increase a grade, not counted towards maximum number of tokens
Students are expected to get up to 20 tokens. Out of those the grade is determined percentage-wise using AGH scale, with 10 tokens as a passing threshold.
For **activity tokens** the activities to choose are as follows:
0-3 tokens per laboratory: ("0" is considered "not prepared", "3" is considered "exceptional performance"), individual grade, 27 tokens max **3 tokens per project:** project organization, discussion, effects and conclusions, group grade, 9 tokens max **4 additional tokens:** correction of laboratory absences
Theoretical maximum of possible-to-acquire tokens is 36. Passing threshold is 15. 5.0 grade threshold is 25. Details of token acquisition are provided in the project instruction during the first meeting

Conditions and the manner of completing each form of classes, including the rules of making retakes, as well as the conditions for admission to the exam

Laboratory tasks are designed by students in cooperation with a teacher, based on chosen project theme. During each laboratory activity tokens are given, using the following scale:
0 - Lack of preparation or lack of sufficient knowledge 1 - Sufficient: The minimum plan is fulfilled 2 - Good: Initiative, ability to expand on basic problems on-the-fly 3 - Exceptional: High initiative, problem-solving skills and high knowledge displayed (in relation to laboratory theme)
During project classes a group grade is assigned based on project design, relevance, lessons learned and results shown. Lecture knowledge is checked using a test and oral answers. Additional activities during lectures can be used to gain additional tokens.

Method of determining the final grade

Weighted average of two grades: knowledge grade (based on knowledge tokens acquired) with weight 0.4 and activity grade (based on activity tokens acquired) with weight 0.6. The final grade can be calculated only if both components are "passed" (min. 3.0)

Manner and mode of making up for the backlog caused by a student justified absence from classes

Absence on classess can be compensated by completing additional tasks defined by the teacher (up to activity 4 tokens can be granted for that)

Prerequisites and additional requirements

The student is familiar with basics of AI and can:
- Design a shallow learning system to solve practical feature-based regression or classification tasks
- Use optimization algorithms (grid search and gradient-based) to optimize hyperparameters of the methods
- Assess the quality of the system using appropriate metrics (accuracy, MAE, MSE, etc.)
- Process signals and images to extract informative features
- Knows basic distance-based and neural-network-based models for classification and regression
- Knows image processing tools and can filter the image using kernel-based filters (including morphology) and extract objects from background
- Knows typical Generative AI solutions and can use them to edit and prepare texts, acquire knowledge, generate and correct codes.
- Knows mechatronic engineering context, including basics of signal processing, control, identification and FEM-based simulations

Rules of participation in given classes, indicating whether student presence at the lecture is obligatory

The lectures are not obligatory. Project classes and laboratory classes are considered obligatory with possibility of being excused if number of tokens acquired is already sufficient for a pass.

Literature

Obligatory

1. Course lecture notes

Optional

1. L. Haupt, Randy and E. Haupt, Sue, PRACTICAL GENETIC ALGORITHMS. Wiley-Interscience, 2004.

Learning outcomes prescribed to a field of study

Code	Content
IMA2A_K01	ability to think and act in an enterprising and creative manner
IMA2A_K02	understanding of the need to formulate and communicate to society, via the media, information and opinions regarding the achievements of mechatronics and other aspects of the activity of a mechatronic engineer in a commonly understandable manner, presenting different points of view
IMA2A_K03	awareness of the social role of a graduate of technical studies, especially as regards the need to formulate and communicate to society, via the media, information and opinions regarding the achievements of mechatronics and other aspects of the activity of a mechatronic engineer; striving to convey such information and opinions in a commonly understandable manner
IMA2A_U01	ability to acquire information from literature, databases and other sources, integrate, interpret and critically assess the information obtained, draw conclusions, formulate and justify opinions
IMA2A_U03	ability to develop detailed documentation related to the completion of an experiment, project or research activity; ability to prepare an elaboration discussing the results obtained
IMA2A_U04	ability to prepare and give a presentation on the completion of a project or research task and conduct a discussion regarding the presentation given
IMA2A_U05	have knowledge of English in the fields of study and disciplines relevant to the field of study at B2+ CEFR level and ability to use specialist terminology in a foreign language
IMA2A_U08	ability to assess and compare design solutions or manufacturing processes of complex mechatronic devices and systems in terms of the functional and economic criteria given
IMA2A_W02	extensive and ordered knowledge of IT techniques applied in mechatronics
IMA2A_W03	extensive knowledge of development trends and most important recent achievements in mechatronics and, to a lesser extent, of automatics, robotics, machine construction, electronics and IT sciences
IMA2A_W07	theory-based extensive knowledge of selected aspects of testing, modelling, designing, production and operation of mechatronic systems and devices, as well as the materials and information processing methods used