# POZNAN UNIVERSITY OF TECHNOLOGY

EUROPEAN CREDIT TRANSFER AND ACCUMULATION SYSTEM (ECTS)

## COURSE DESCRIPTION CARD - SYLLABUS

Course name
Advanced diagnostics and monitoring systems [S2AiR2-ISA>ZSDiM]

### Course

Field of study
Automatic Control and Robotics

Year/Semester
1/2

Area of study (specialization)
Intelligent Control Systems

Profile of study
general academic

Level of study
second-cycle

Course offered in
Polish

Form of study
full-time

Requirements
compulsory

### Number of hours

Lecture
30

Laboratory classes
30

Other
0

Tutorials
0

Projects/seminars
0

### Number of credit points
4,00

### Coordinators

dr inż. Dominik Łuczak
dominik.luczak@put.poznan.pl

### Lecturers

### Prerequisites

Knowledge: The student starting this course should have knowledge of automation and robotics corresponding to the 6th level of the Polish Qualifications Framework, in particular knowledge of the analysis of automation models, data structures, complex numbers, basics of signal processing. Skills: The student should have the ability to analyze and implement control and measurement systems in the field of automation and robotics and the ability to obtain information from the indicated sources. They should also understand the need to expand their competences and be ready to cooperate in a team. Social competences: In addition, in terms of social competences, the student must show such qualities as honesty, responsibility, persistence, cognitive curiosity, creativity, personal culture, respect for other people.

### Course objective

1. Provide students with knowledge about the methods used in monitoring and diagnostic systems. 2. Developing students' skills to develop automatic monitoring and diagnosis systems with the use of available signal processing techniques. 3. Shaping in students the importance of knowledge of technology and recommendations related to automatic monitoring and diagnostics of devices.

### Course-related learning outcomes

Knowledge:
1. The student has an ordered and detailed knowledge of artificial intelligence methods and their application in automation and robotics systems; [K2_W2]
2. has specialist knowledge of remote and distributed systems, real-time systems and network techniques; [K2_W3]
3. has detailed knowledge of the construction and use of advanced sensory systems; [K2_W6]
4. has a basic knowledge of the life cycle of automation and robotics systems as well as control and measurement systems; [K2_W13]

Skills:
1. The student is able to assess the usefulness and the possibility of using new achievements (including techniques and technologies) in the field of automation and robotics; [K2_U16]
2. can construct an algorithm for solving a complex and unusual engineering task and a simple research problem and implement, test and run it in a selected programming environment for selected operating systems; [K2_U25]
3. is able to construct an algorithm for solving a complex and untypical measurement and computational-control task and implement, test and run it in a selected programming environment on a microprocessor platform; [K2_U26]

Social competences:
1. The student is aware of the need for a professional approach to technical issues, meticulous familiarization with the documentation and environmental conditions in which devices and their components can function; [K2_K4]

## Methods for verifying learning outcomes and assessment criteria

Learning outcomes presented above are verified as follows:

The learning outcomes presented above are verified in the following way:
Formative assessment:
a) in terms of lectures:
based on homework assignments and answers to questions about the material covered in previous lectures,
b) within the scope of the laboratory:
based on the assessment of knowledge and understanding of current issues presented in the course.
c) In both forms of classes, it is possible to use Problem-Based Learning (PBL) tasks that support the current research and technical needs of the course coordinator and are supervised by the instructor, taking into account the iterative and cyclical nature of task implementation, provided that they are consistent with the course content.

Summary rating:
a) in the field of lectures, verification of the assumed learning outcomes is carried out by:
i. assessment of knowledge and skills demonstrated in the form of a multiple-choice test,
ii. discussion of the test results.
b) in the laboratory, verification of the assumed learning outcomes is carried out by:
i. assessment of the student's preparation for individual classes,
ii. continuous assessment in each class (oral answers) - rewarding the increase in the ability to use the learned principles and methods,
iii. assessment of tasks prepared partly during classes, as well as after their completion.
c) The summative assessment may include the results of Problem-Based Learning (PBL) assignments developed for the research and technical needs of the course coordinator and supervised by the instructor, provided they are consistent with the course curriculum.
d) Obtaining additional points for activity during classes, in particular for:
i. independent construction of a distributed monitoring and diagnostics system consisting of several electronic modules with microprocessors communicating in real time and preparation of documentation,
ii. effectiveness of applying acquired knowledge when solving a given problem
iii. comments related to the improvement of teaching materials.

## Programme content

The subject covers a wide range of issues related to diagnostics and monitoring of devices, with particular emphasis on electromechanical devices. Students learn the types of damage, types of measurement signals, the theory of digital measurements, as well as advanced methods of signal analysis and system modeling.

In the first part of the program, students become familiar with diagnostics and monitoring of devices using data sets (non-parametric models). This includes frequency analysis, time-frequency analysis, time-scale analysis, sliding frequency analysis, signal demodulation and decomposition techniques, and frequency spectrum modification and improvement.

In the second part of the program, students learn about diagnostics and monitoring of devices using parametric models. This includes methods of collecting data for building models, selected forcing signals, simplified parametric models, types of parametric models, methods of model transformation, obtaining and evaluating a discrete parametric model based on frequency response, obtaining and evaluating a continuous parametric model based on frequency response, and the nonlinear method of least squares.

In the third part of the program, students learn about insulation and fault location. This includes a binary classifier, a multi-class classifier built on supervised and semi-supervised machine learning algorithms, as well as research and development involving diagnostics and device monitoring systems.

Laboratory classes give students the opportunity to practically apply the acquired knowledge. They include familiarization with the equipment, data representing the monitored electromechanical system, data visualization, analysis of data from the system, signal analysis techniques, analysis of excitation signals and obtained responses, determination and evaluation of parametric models, construction and evaluation of classifiers, and presentation of the final task.

The course program provides comprehensive preparation for work in the field of device diagnostics and monitoring. Students will gain theoretical knowledge and practical skills necessary to identify and locate faults in various types of systems.

## Course topics

The lecture program covers the following topics:
1. Introduction to diagnostics and monitoring of devices, in particular electromechanical devices. Types of damage. Types of measurement signals. The theory of digital measurements.
Section I. Diagnostics and monitoring of devices with the use of data sets (nonparametric models).
2. Frequency analysis.
3. Time-frequency analysis.
4. Time-scale analysis.
5. Sliding frequency analysis.
6. Technique of demodulation and decomposition of signals.
7. Modification and improvement of the frequency spectrum.
Section II. Diagnostics and monitoring of devices using parametric models.
8. Data collection methods for building models. Selected signals forcing e.g. chirp, PRBS, Kronecker pulse.
9. Simplified parametric models. Types of parametric models. Ways of model transformation.
10. Obtaining and evaluating a discrete parametric model based on the frequency response.
11. Obtaining and evaluating a continuous parametric model based on the frequency response. Nonlinear least squares method.
Division III. Isolation and fault location
12. Binary classifier.
13. A multi-class classifier built on the basis of supervised and partially supervised machine learning algorithms.
14. R&D works including device diagnostics and monitoring systems.
15. Summary.

The laboratory program includes:
1. Organizational classes - familiarization with equipment and OHS footnotes, introduction to the design environment.
2. Getting acquainted with data representing the monitored electromechanical system. Preparation of data visualization and presentation of fragments from the data set.
3. Frequency analysis of system data (simulation or real data).

4. Time-frequency analysis.
5. Time-scale analysis.
6. Sliding frequency analysis.
7. Techniques of demodulation and decomposition of signals.
8. Modification and improvement of the frequency spectrum.
9. Analysis of forcing signals and obtained responses. Frequency response data analysis.
10. Determination and evaluation of discrete models.
11. Determination and evaluation of continuous models.
12. Construction and evaluation of a binary classifier.
13. Application and evaluation of a group of binary classifiers. Building a multi-class classifier.
14. Application and evaluation of the multi-class classifier.
15. Presentation of the final task: the monitoring and diagnosis system for selected system elements.

## Teaching methods

1. Lecture: presentation of the use of frequency analysis for an electromechanical system, a multimedia presentation illustrated with literature data and sample projects
2. Laboratory classes: using data from a simulated / real electromechanical system as input data, simulation environment for designing and implementing a monitoring and diagnostic system
3. Both forms of instruction offer the opportunity to incorporate elements of Problem-Based Learning (PBL), in which students work on problems and projects defined for the research and technical needs of the course coordinator and supervised by the instructor. This approach places particular emphasis on the iterative nature of work, encompassing problem analysis, solution design, practical verification, and systematic refinement.

## Bibliography

Basic
1. Łuczak, D. Data-Driven Machine Fault Diagnosis of Multisensor Vibration Data Using Synchrosqueezed Transform and Time-Frequency Image Recognition with Convolutional Neural Network. Electronics 2024, 13, 2411, doi:10.3390/electronics13122411.
2. Łuczak, D. Machine Fault Diagnosis through Vibration Analysis: Time Series Conversion to Grayscale and RGB Images for Recognition via Convolutional Neural Networks. Energies 2024, 17, 1998, doi:10.3390/en17091998.
3. Łuczak, D. Mechanical Vibrations Analysis in Direct Drive Using CWT with Complex Morlet Wavelet. Power Electron. Drives 2023, 8 (43), 65–73, doi:10.2478/pead-2023-0005.
4. Łuczak, D. Nonlinear Identification with Constraints in Frequency Domain of Electric Direct Drive with Multi-Resonant Mechanical Part. Energies 2021, 14, 7190, doi:10.3390/en14217190.
5. Brock, S.; Łuczak, D.; Nowopolski, K.; Pajchrowski, T.; Zawirski, K. Two Approaches to Speed Control for Multi-Mass System with Variable Mechanical Parameters. IEEE Trans. Ind. Electron. 2017, 64, 3338–3347, doi:10.1109/TIE.2016.2598299.
6. Łuczak, D.; Skrzypiński, M. Filtration of Digital Signals Using Wavelets. Poznan Univ. Technol. Acad. J. Electr. Eng. 2016, 187--195.
7. Łuczak, D.; Nowopolski, K. Identification of Multi-Mass Mechanical Systems in Electrical Drives. In Proceedings of the 2014 16th International Conference on Mechatronics - Mechatronika (ME); December 2014; pp. 275–282.
8. Łuczak, D. Mathematical Model of Multi-Mass Electric Drive System with Flexible Connection. In Proceedings of the Methods and Models in Automation and Robotics (MMAR), 2014 19th International Conference On; Miedzyzdroje, Poland, September 2014; pp. 590–595.
9. Fault Detection and Diagnosis of Industrial Robot Based on Power Consumption Modeling, Ahmad H. Sabry i inni, 2020, https://doi.org/10.1109/TIE.2019.2931511
10. Gudovskiy, Denis A., and Lichung Chu. "An Accurate and Stable Sliding DFT Computed by a Modified CIC Filter [Tips & Tricks]." IEEE Signal Processing Magazine 34.1 (2017): 89-93., https://doi.org/10.1109/MSP.2016.2620198
11. Jacobsen, Eric, and Richard Lyons. "The sliding DFT." IEEE Signal Processing Magazine 20.2 (2003): 74-80., https://doi.org/10.1109/MSP.2003.1184347

Additional
1. Comparison of fault tolerant control algorithm using space vector modulation of PMSM drive, Łuczak i Siembab, 2014, https://doi.org/10.1109/MECHATRONIKA.2014.7018231

2. Diagnostyka drganiowa stanu maszyn i urządzeń / Józef Dwojak, Marek Rzepiela ; konsultacje techniczne Grzegorz Jezierski, 2005.

## Breakdown of average student's workload

| | Hours | ECTS |
|---|---|---|
| Total workload | 100 | 4,00 |
| Classes requiring direct contact with the teacher | 60 | 2,50 |
| Student's own work (literature studies, preparation for laboratory classes/ tutorials, preparation for tests/exam, project preparation) | 40 | 1,50 |