GDAŃSK UNIVERSITY OF TECHNOLOGY

Subject card

Subject name and code	Optimization and Decision Support, PG_00056863		
Field of study	Automation, Robotics and Control Systems		
Date of commencement of studies	October 2023	Academic year of realisation of subject	2024/2025
Education level	first-cycle studies	Subject group	
Mode of study	Full-time studies	Mode of delivery	at the university
Year of study	2	Language of instruction	Polish
Semester of study	4	ECTS credits	5.0
Learning profile	general academic profile	Assessment form	exam
Conducting unit	Department of Control Engineering -> Faculty of Electrical and Control Engineering		
Name and surname of lecturer (lecturers)	Subject supervisor	dr hab. Anna Witkowska	
	Teachers	dr hab. Anna Witkowska	

Lesson types and methods of instruction

Lesson type	Lecture	Tutorial	Laboratory	Project	Seminar	SUM
Number of study hours	30.0	24.0	6.0	0.0	0.0	60

E-learning hours included: 0.0

Additional information:
Lecture, exercises, laboratory - classes conducted in a stationary form

Exercises - blackboard exercises, presentation of solutions, discussion

Lecture - conventional lecture, presentation of content, discussion

Computer laboratories - practical and independent implementation of tasks on a computer workstation.

Learning activity and number of study hours

Learning activity	Participation in didactic classes included in study plan	Participation in consultation hours	Self-study	SUM
Number of study hours	60	8.0	57.0	125

Subject objectives

The aim of the course is for the student to master the knowledge of optimisation theory and decision support. The student will be introduced to static optimisation and decision support algorithms and their application in automation systems. In addition, the student will master the ability to optimally select control system parameters.

Learning outcomes

Course outcome	Subject outcome	Method of verification
[K6_K05] can think and act in an entrepreneurial way	Uses optimisation methods in solving problems in various fields, e.g. calculates profit-maximising, loss-minimising production volumes, solves a transport problem.	[SK5] Assessment of ability to solve problems that arise in practice
[K6_U05] can use analytical and simulation methods to solve tasks in the field of automation and robotics and use various techniques to carry out engineering tasks related to automation and robotics devices and systems	Determines optimal control system parameters using numerical optimisation methods. Uses analytical and numerical optimisation methods to identify parametric models.	[SU1] Assessment of task fulfilment
[K6_W01] has basic knowledge in the field of mathematics including algebra, geometry, mathematical analysis, probabilistics, numerical methods - necessary to describe and analyze automation and robotics systems	Defines an optimization problem in the form of a mathematical model – specifies the objective function, decision variables, and constraints. Determines the necessary conditions for optimizing a differentiable function of several variables, with and without constraints.	[SW1] Assessment of factual knowledge

Subject contents	**Lecture**: Introduction to the mathematical theory of optimization. Formulation of optimization problems, classification of optimization problems, examples, mathematical description. Convex optimization problems - convex sets and convex functions. Extrema of functions of several variables. Classification of extrema. Representations of criterion functions. Geometric methods of optimization (2D problems). Analytical and iterative methods for determining extrema. Linear, quadratic, and convex programming. Static optimization without constraints for differentiable criterion functions. Necessary and sufficient conditions for the existence of extrema for single-variable and multivariable functions. Sylvester's theorem on quadratic forms. Static optimization for problems with equality constraints conditions for the existence of conditional extrema. Lagrange multiplier method for problems with equality constraints. Static optimization with inequality and mixed constraints conditions for the existence of extrema. Kuhn-Tucker theorem. Iterative methods for searching for extrema for unconstrained problems general characteristics and classification. Gradient-free optimization methods, directional search methods, simple search methods. Gradient methods of improvement directions, global minimum search methods. Formulation of multi-criteria optimization problems. Efficient solutions vs. compromise solutions. Methods for obtaining compromise solutions for multi-objective linear programming problems (WPL). Pareto front, dominated and non-dominated solutions, Pareto cone. Multi-objective and multi-attribute decision support. Dynamic optimization, problem formulation, and examples of applied solutions. **Exercises**: Formulating a mathematical model of an optimization problem and classification based on selected problems. Determining necessary and sufficient conditions for the optimization of a convex function of several variables, application of classical calculus methods based on gradient and Hessian, and variable elimination method. Solving linear and quadratic programming problems using geometric and analytical methods parameter selection for the model. Discrete optimization using the transportation problem as an example. Lagrange method for problems with equality constraints selected examples with solutions. Kuhn-Tucker method for problems with inequality constraints selected examples with solutions. Numerical optimization methods (e.g., Gauss-Seidel, simple gradient, steepest descent, Newton). Determining stopping conditions for numerical optimization algorithms. Identifying sets of non-dominated and efficient solutions in multi-criteria optimization problems. Solutions in decision space and objective function space. Determining compromise solutions based on meta-criteria methods and criteria hierarchy. Bellman's principle of optimality. **Laboratory**: Application of numerical optimization algorithms to select control system parameters using Matlab. Analysis of the influence of initial conditions, optimization algorithm parameters, and stopping conditions on the solution, followed by analysis and discussion.
Prerequisites and co-requisites	Knowledge of the compulsory subjects of the course. Basic knowledge of the Matlab environment.

Assessment methods and criteria

Subject passing criteria	Passing threshold	Percentage of the final grade
excercises	50.0%	40.0%
lecture	50.0%	40.0%
labolatory	50.0%	20.0%

Recommended reading

Basic literature	• Amborski, Podstawy metod optymalizacji, Oficyna Wydawnicza Politechniki Warszawskiej, 2001 • Arabas G.: Wykład z algorytmow ewolucyjnych, PWN, Warszawa 2003. • Kusiak Jan , Danielewska-Tułecka Anna , Oprocha Piotr . Optymalizacja. Wybrane metody z przykładami zastosowań. Wydawnictwo Naukowe PWN 2009. • Marianna Jacyna. Wspomaganie decyzji w praktyce inżynierskiej. PWN. Warszawa 2022.
Supplementary literature	• P.E.Gill, W.Murray, M.H.Wright, Practical Optimization.
eResources addresses	Adresy na platformie eNauczanie: OPTYMALIZACJA I WSPOMAGANIE DECYZJI [ARiSS][2024/25] - Moodle ID: 42855 https://enauczanie.pg.edu.pl/moodle/course/view.php?id=42855

Example issues/ example questions/ tasks being completed	Example 1. The electrical nodes there are receivers receiving currents shown on the drawing. How do I connect (which segments of he electrical web) the final receivers from the supply point to minimise the voltage drop between them Example2. The company produces two products: W1 and W2 of three materials: S1, S2 and S3. For manufacturing of the product W1 needs 2 units of S1, one unit of S2 , and 4 units of S3. To produce a product W2 respectively needs 2 units of S1 , 2 units of S2. Daily limit is: 14 units of S1, 8 - S2 and 16 - S3. Product prices are as follows: 2 zł for W1 and 3 zł for W2. Find the production plan to maximize the benefits from the sale by using graphical method. Example 3. Application of numerical optimization algorithms to the tuning of PID controller parameters on the example of optimization of a ship's course control system with Nomoto first-order model.
Work placement	Not applicable