GDAŃSK UNIVERSITY OF TECHNOLOGY

Subject card

Subject name and code	, PG_00071495						
Field of study	Automation, Robotics and Control Systems						
Date of commencement of studies	October 2024		Academic year of realisation of subject		2025/2026		
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		1.0		
Learning profile	general academic profile		Assessment form		assessment		
Conducting unit	Department of Control Engineering -> Faculty of Electrical and Control Engineering -> Faculties of Gdańsk University of Technology						
Name and surname of lecturer (lecturers)	Subject supervisor		dr hab. Anna Witkowska				
	Teachers		dr hab. Anna Witkowska				

Lesson types	Lesson type	Lecture	Tutorial	Laboratory	Project	Seminar	SUM
	Number of study hours	10.0	15.0	0.0	0.0	0.0	25
	E-learning hours included: 0.0						

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	25	0.0	0.0	25

Subject objectives	The aim of the course is to familiarize students with evolutionary optimization methods and to develop their ability to apply them in the design of control systems used in automation and robotics. In particular, students learn the principles of genetic algorithms and their application to the optimization of controller parameters. During the practical classes, students implement and analyze a genetic algorithm used for tuning a ship course controller for a ship dynamics model. Students also learn how to interpret optimization results and evaluate the performance of the control system using selected performance indices.

Learning outcomes	Course outcome	Subject outcome	Method of verification
	[K6_U07] can build and analyze models of systems and systems in the field related to control systems and automation	The student implements and analyzes a dynamic model of a marine vessel control system and formulates an optimization problem model. In particular, the student applies optimization algorithms to determine the parameters of a controller in a control system model.	[SU1] Assessment of task fulfilment
	[K6_W08] knows the basics of equipment selection and control of electrical machines and servos	The student understands the operating principle of a ship steering gear as a servomechanism used for rudder positioning.	[SW1] Assessment of factual knowledge
	[K6_U02] can work individually and in a team, can communicate using various techniques in a professional environment, as well as document and analyze the results of their work, can estimate the time needed to perform the entrusted task can prepare and present a presentation on the problems and results of an engineering task	The student individually and collaboratively performs tasks related to the implementation and analysis of optimization algorithms in control systems, documents the course of conducted experiments, and interprets and presents the obtained results. The student also estimates the time required to complete the assigned task.	[SU4] Assessment of ability to use methods and tools

Subject contents	Course content – lecture **1. Introduction to optimization problems in automation and robotics (2 hours)** Basic concepts of optimization. Formulation of an optimization problem: objective function, decision variables, and constraints. Examples of optimization problems in control systems and automation. **2. Optimization methods used in automation (2 hours)** Classical optimization methods: gradient-based methods and search of the solution space. Problems of local extrema. Introduction to heuristic and metaheuristic methods. **3. Evolutionary algorithms and genetic algorithms (2 hours)** Biologically inspired approaches to optimization. Structure of a genetic algorithm: population, selection, crossover, and mutation. Chromosome representation and fitness function. **4. Analysis of genetic algorithm performance (2 hours)** Influence of genetic algorithm parameters on the optimization process. Algorithm convergence, stability of results, and population stagnation. Trade-off between exploration and exploitation of the solution space. **5. Applications of optimization algorithms in control systems (2 hours)** Optimization of controller parameters. Controllers and control performance indices. Ship dynamics model and the use of genetic algorithms for optimizing controller parameters in a ship control system. Course content – exercises **1. Modeling of a ship control system (3 hours)** Introduction to the ship dynamics model described by the BechWagner model. Implementation of the model in a computational environment. Analysis of the system response and identification of basic model parameters. **2. Implementation of a controller in the ship control system (3 hours)** Development of a control system model with a controller. Analysis of the influence of controller parameters on system dynamics. Evaluation of control performance using selected performance indices. **3. Implementation of a genetic algorithm for controller parameter optimization (3 hours)** Structure of a genetic algorithm: chromosome representation, fitness function, and operators of selection, crossover, and mutation. Implementation of a genetic algorithm used to optimize controller parameters. **4. Analysis of the influence of genetic algorithm parameters (3 hours)** Investigation of the influence of genetic algorithm parameters (population size, crossover probability, mutation probability, number of generations) on the optimization process. Analysis of algorithm convergence and the phenomenon of population stagnation. **5. Analysis of algorithm stability and interpretation of optimization results (3 hours)** Evaluation of the stability of the genetic algorithm through repeated runs of the algorithm. Analysis of the trade-off between exploration and exploitation of the solution space. Interpretation of the obtained results and assessment of control system performance.
Prerequisites and co-requisites	

Assessment methods and criteria	Subject passing criteria	Passing threshold	Percentage of the final grade
	Practical exercise	50.0%	100.0%

Recommended reading	Basic literature	1. Jarosław Arabas. Wykłady z algorytmów ewolucyjnych. WNT. 2004 2. Saadeh, Mohammed. Grokking Algorithms. https://www.academia.edu/41263398/Grokking_Algorithms 3. Identification of the nonlinear ship model parameters based on the turning test trial and the backstepping procedure. Manuel Haro Casado, Ramo´n Ferreiro. Ocean Engineering 32 (2005) 13501369. https://bibrepo.uca.es/articuloscientificos/31776139.pdf

	Supplementary literature	3. Mirosław Tomera. [Wielooperacyjne sterowanie ruchem statku w układzie o strukturze przełączalnej](). 2018
	eResources addresses	
Example issues/ example questions/ tasks being completed	1. In the Simulink environment, a mathematical model of ship dynamics should be developed. The dynamic equations describing the hull dynamics, including the state equations and the output equation, should be modeled in two ways. The first approach consists of creating a simulation model in Simulink using integrator blocks, while the second approach involves implementing the model as an m-file in the form of an S-function. **1.** Build a control system model with a PID controller in Simulink and initially tune the gains KP, KI, and KD, aiming to achieve a short settling time and low overshoot. Analyze the variations of the signals e(t) and u(t). **2.** Run the genetic algorithm and perform experiments by changing the number of generations, population size, and the probabilities of crossover and mutation. Analyze how these parameters influence the obtained controller gains.	
Practical activites within the subject	Not applicable	

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