GDAŃSK UNIVERSITY OF TECHNOLOGY

Subject card

Subject name and code	Genetic Algorithms, PG_00068275		
Field of study	Automatic Control, Cybernetics and Robotics		
Date of commencement of studies	October 2025	Academic year of realisation of subject	2027/2028
Education level	first-cycle studies	Subject group	Optional subject group Subject group related to scientific research in the field of study
Mode of study	Full-time studies	Mode of delivery	at the university
Year of study	3	Language of instruction	Polish
Semester of study	6	ECTS credits	2.0
Learning profile	general academic profile	Assessment form	assessment
Conducting unit	Department of Decision Systems and Robotics -> Faculty of Electronics Telecommunications and Informatics -> Wydziały Politechniki Gdańskiej		
Name and surname of lecturer (lecturers)	Subject supervisor	dr inż. Tomasz Białaszewski	
	Teachers	dr inż. Tomasz Białaszewski	

Lesson types and methods of instruction	Lesson type	Lecture	Tutorial	Laboratory	Project	Seminar	SUM
	Number of study hours	15.0	0.0	15.0	0.0	0.0	30
	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	30	2.0	18.0	50

Subject objectives	The aim of the course is to familiarize students with the theory and practical application of evolutionary algorithms, particularly genetic algorithms, as an effective method for optimization and solving computational problems. Students will explore the biological inspirations behind evolutionary algorithms, as well as methods for designing, implementing, and analyzing their effectiveness. Throughout the course, both classical optimization techniques and advanced heuristic methods will be discussed, with an emphasis on finding global solutions in high-complexity problems. Students will learn techniques for representing candidate solutions, defining fitness functions, applying genetic operators, and implementing various selection and niching strategies to improve algorithm efficiency. An additional goal is to understand the theoretical foundations of genetic algorithms, such as schema theory, and to develop practical skills in applying evolutionary algorithms to optimize parameters and structures of engineering systems, multi-objective problems, and genetic programming.

Learning outcomes	Course outcome	Subject outcome	Method of verification
	[K6_W21] knows and understands the basic methods of decision making as well as methods and techniques of design and operation of automatic regulation and control systems, computer applications for controlling and monitoring dynamic systems.	The student knows how to analyze the effectiveness of genetic algorithms and select optimal control parameters. The student understands and can apply advanced techniques such as fitness scaling, niching, selection of multi-objective solutions.	[SW3] Assessment of knowledge contained in written work and projects [SW1] Assessment of factual knowledge
	[K6_U01] can apply mathematical knowledge to formulate and solve complex and non-typical problems related to the field of study and perform tasks, in an innovative way, in not entirely predictable conditions, by:n- appropriate selection of sources and information obtained from them, assessment, critical analysis and synthesis of this information,n- selection and application of appropriate methods and toolsn	The student is able to design and implement genetic algorithms in the Python environment. The student can apply evolutionary algorithms to solve real-world optimization problems.	[SU4] Assessment of ability to use methods and tools [SU3] Assessment of ability to use knowledge gained from the subject
	[K6_W01] knows and understands, to an advanced extent, mathematics necessary to formulate and solve simple issues related to the field of study	The student understands and interprets the results of algorithm performance in the context of schema theory and evolutionary strategies.	[SW1] Assessment of factual knowledge [SW3] Assessment of knowledge contained in written work and projects

Subject contents	Lecture: 1. Course Structure Overview. Presentation of Assessment and Grading Criteria. 2. A review of the biological inspirations behind genetic algorithms, such as mechanisms of inheritance, mutation, recombination, and natural selection. A comparison between biological evolution and the processes used in optimization algorithms. 3. Discussion of classical optimization methods, including gradient-based methods, dynamic optimization, linear and nonlinear programming. A comparison of their effectiveness with heuristic and evolutionary approaches in the context of complex computational problems. 4. Classification of optimization methods based on their search strategies within the solution space. An analysis of the effectiveness of different approaches depending on the type of problem. 5. Description of the general structure of a genetic algorithm, its fundamental components (population, selection, crossover, mutation). Key parameters influencing the effectiveness of the evolutionary process. 6. Solution encoding methods in genetic algorithms: binary, real-valued, and permutation representations, among others. Approaches to decoding genotypes into phenotypes and their impact on the efficiency of searching for optimal solutions. 7. Defining the fitness function and its significance in the evolutionary process**.** An overview of methods for evaluating the quality of individuals, such as cost functions, ranking, normalization, and various fitness scaling techniques. 8. Discussion of selection methods for individuals in subsequent generations: roulette wheel selection, tournament selection, ranking selection, elitist selection. A comparison of their impact on the speed and efficiency of optimization. 9. Analysis of genetic operators: crossover (single-point, two-point, uniform, arithmetic), mutation (random, non-uniform, adaptive), and their influence on the diversification and exploration of the solution space. 10. Population management strategies across generations: full population replacement, elitist strategies, partial replacement mechanisms, and their significance for convergence speed and avoiding premature convergence. 11. Modifications to the fitness function to improve selection efficiency. Linear, power-based, and standard deviation scaling. 12. Introduction to schema theory as a tool for analyzing the behavior of genetic algorithms. Discussion of Hollands schema theorem and its implications for designing effective genetic operators. 13. Overview of techniques to prevent premature convergence of the population to a single solution: crowding, niching, and their application in multimodal optimization problems. 14. Application of evolutionary algorithms to multi-objective problems. Overview of popular methods such as NSGA-II (Nondominated Sorting Genetic Algorithm) and MOEA/D (Multi-Objective Evolutionary Algorithm based on Decomposition). 15. Review of practical applications of genetic and evolutionary algorithms in engineering design optimization, neural networks, electronic circuit design, mechanics, robotics, and other domains. Laboratory: Implementation of Methods: 1. Encoding solutions for a given optimization problem 2. Transforming the objective function for the defined optimization task\\ 3. Selection methods 4. Crossover and mutation operators 5. Replacement strategies 6. Niching techniques 7. Evaluation of multi-objective problems Application of the implemented genetic algorithm mechanisms to build a selected version of GA for the given optimization problem
Prerequisites and co-requisites	
Assessment methods and criteria	see table below

Subject passing criteria	Passing threshold	Percentage of the final grade
Assessment by exam	50.0%	60.0%
Laboratory work execution	50.0%	40.0%

Recommended reading	Basic literature	Arabas J.: Wykłady z algorytmów ewolucyjnych. WNT, Warszawa 2001. Berg P., Singer M.: Język genów, poznawanie zasad dziedziczenia. Prószyński i S-ka, Warszawa 1997. Goldberg D.E.: Genetic algorithms in search, Optimisation and Machine Learning. Addison-Wesley, Massachusetts 1989. Michalewicz Z., Fogel D. B.: How to solve it: Modern Heuristics. 2nd edition, Springer-Verlag, Berlin 2004. Michalewicz Z.: Genetic Algorithms + Data Structures = Evolution Programms, Springer-Verlag, 3rd edition, Heidelberg - Berlin 1996. Miller R. E.: Optimization. Foundations and applications. A Wiley-Interscience Publication, John Wiley & Sons, Inc. New York 2000. Obuchowicz A.: Evolutionary Algorithms for Global Optimization and Dynamic System Diagnosis. Lubusky Scientific Society in Zielona Góra 2003. Rutkowski L.: Metody i techniki sztucznej inteligencji. Wydawnictwo Naukowe PWN, Warszawa 2005.
	Supplementary literature	Koza J. R.: Genetic Programming: On the Programming of Computers by Means of Natural Selection. The MIT Press, MA, Cambridge 1992. Man K.S, Tang K.S., Kwong S., Lang W.A.H.: Genetic Algorithms for Control and Signal Processing. Springer-Verlag, London 1997.
	eResources addresses	
Example issues/ example questions/ tasks being completed	1. Is it possible that a genetic algorithm without the mutation mechanism peaked global fitness function? 2. The population consists of 4 individuals with the following fitness degrees: 169, 576, 64 and 361. Determine the scaled fitness degree of individuals using the linear scaling with the multiplication factor equal to 2. 3. Assuming that an individual matching the pattern S has a degree of adaptation higher than the average of adapting the current population of 25%, determine in which generation scheme that monopolize population of 20, 50, 100 and 200 individuals. For calculations ignore the effect of crossover and mutation. 4. Please give the principle of mutation for trialleic coding. 5. List and briefly review the operations of crossing with floating-point representation. 6. A solution space contains 2097152 points. Enter the lower and upper estimate of the number of patterns processed during the evolutionary cycle to encode binary and octal encoding. Assuming that the population consists of 50 individuals.	
Work placement	Not applicable	