GDAŃSK UNIVERSITY OF TECHNOLOGY

Subject card

Subject name and code	Data Processing Methods in Automation, PG_00064526		
Field of study	Automatic Control, Cybernetics and Robotics		
Date of commencement of studies	February 2027	Academic year of realisation of subject	2026/2027
Education level	second-cycle studies	Subject group	Optional subject group Specialty 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	1	Language of instruction	Polish
Semester of study	1	ECTS credits	2.0
Learning profile	general academic profile	Assessment form	assessment
Conducting unit	Department of Signals and Systems -> Faculty of Electronics Telecommunications and Informatics -> Faculties of Gdańsk University of Technology		
Name and surname of lecturer (lecturers)	Subject supervisor	dr inż. Kamil Stawiarski	
	Teachers	dr inż. Kamil Stawiarski dr inż. Piotr Kaczmarek	

Lesson types	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	4.0	16.0	50

Subject objectives

The purpose of the lectures is to familiarize students with advanced mathematical issues, theoretical and practical methods used in signal analysis and processing, as well as radar systems.

Part 1:
Students will gain knowledge of signal analysis using complex numbers, differentiation of complex functions, and IQ modulation methods. In linear algebra topics, he will learn the applications of matrices as linear transformations, eigenvalue issues, diagonalization, SVD decomposition, and PCA analysis, especially in the context of signal and image processing. In addition, the student will learn the basics of random signal theory, correlation, and adaptive filtering with its practical applications, including state vector tracking, echo cancellation, and telecommunications channel equalization.

Part 2:
The student will gain an understanding of the design and operation of radar systems, considering the structure of antennas, transmit and receive paths, and how radar signals are processed. He or she will learn various signal filtering methods, such as matched or Doppler filtering, as well as advanced detection techniques, including CFAR algorithms.Within the framework of estimation issues, the student will learn methods for determining object parameters such as distance, radial velocity or signal reception angle, taking into account issues related to estimation accuracy (MSE, CRLB) and measurement ambiguity.

As a result, the student will be able to analyze complex signal processing systems, use advanced mathematical techniques and apply the acquired knowledge to practical tasks in automation, telecommunications and radar systems

Learning outcomes	Course outcome	Subject outcome	Method of verification
	[K7_U07] can apply advanced methods of process and function support, specific to the field of study	Upon completion of the course, the student is able to use advanced methods to support the analysis and processing of signals and data detection, estimation and filtering functions in radar and telecommunications systems. He knows how to apply mathematical techniques, numerical algorithms and software tools to optimize the performance of technical systems. Demonstrates the ability to integrate various methods to increase the efficiency and accuracy of implemented processes.	[SU4] Assessment of ability to use methods and tools
	[K7_W03] knows and understands, to an increased extent, the construction and operating principles of components and systems related to the field of study, including theories, methods and complex relationships between them and selected specific issues - appropriate for the curriculum	Upon completion of the course, the student knows and understands to an in-depth degree the construction and operating principles of components and systems related to signal analysis and processing and radar technology. He can apply advanced mathematical methods and algorithms for data analysis, signal filtering, detection and estimation of object parameters. Understands the complex interrelationship between theory and practice and the impact of system parameters on the accuracy and reliability of technical systems.	[SW3] Assessment of knowledge contained in written work and projects
	[K7_W04] knows and understands, to an increased extent, the principles, methods and techniques of programming and the principles of computer software development or programming devices or controllers using microprocessors or other elements or programmable devices specific to the field of study, and organization of work of systems using computers or such devices	Upon completion of the course, the student knows and understands to an in-depth degree the principles, methods and techniques of programming signal processing systems and devices using microprocessors and programmable circuits. He can design and implement algorithms for signal analysis, filtering, detection and estimation, taking into account the specifics of radar and telecommunications systems. Understands the organization of computer systems and control devices, as well as the impact of the programming methods used on the efficiency and reliability of system operation.	[SW3] Assessment of knowledge contained in written work and projects

Subject contents	Course content – lecture Part 1: W1: -composite numbers, -complex sine, -IQ modulation, -differentiation of composite functions W2: -basic operations on matrices, -matrices as linear transformations, -linear spaces, -base and kernel transformations, -reference to state models W3: -Eigenvalues, eigenvectors, -decomposition of matrices (diagonalization, SVD), PCA analysis W4: -Applications of diagonalization, SVD, PCA in signal processing, image processing and automation W5,6: -basic information about random signals, -correlation of signals, -basics of adaptive filtering, W7: -application of adaptive filtering: for state vector tracking (moving object tracking issues), in echo and vibration suppression tasks, telecommunication channel equalization Part 2: W1: - Construction of radar, antenna - Description of the transmitting / receiving part - Use of signals in the form of complex numbers - Signal flow, mixer operation, reduction to baseband - Concept of data cube - Pulse radar vs. FMCW W2: - Matched filtering - explanation of the issue - Different types of waveforms - Relationship between bandwidth and duration and sidelobe level, gain - Differences in pulse radar vs. FMCW - Expanding the topic to communication issues, looking at it in terms of object identification W3: - Beamforming - purpose of application, antenna characteristics

	- Effect of antenna array, discussion of sparse arrays - Effect of taper on beamforming, purpose of using them W4: - Doppler filtering - Description of the Doppler effect itself - Purpose of application - Unambiguity of radial velocity measurement W5: - Detection - purpose, examples of signals - CFAR - description of the algorithm, its different variants - Dependence of probability of detection and false alarm on SNR - Detection of several objects in its environment, introduction to OS CFAR, its advantages W6 - Estimation, introduction to the issue as an estimator of object parameters - Distance estimation, variant with non-uniform measurement - Radial velocity estimation, ambiguous measurement W7 - Estimation of the angle of signal reception - physical description - Exact signal model, approximate model - Frequency dependence - Non-parametric model using monoimpulse as an example - MSE - maximum likelihood estimator - CRLB - estimation of the minimum variance of the unloaded estimator
Prerequisites and co-requisites	Knowledge of linear algebra, fundamentals of filtering and signal processing.

Assessment methods and criteria

Subject passing criteria	Passing threshold	Percentage of the final grade
Lecture credit colloquium	50.0%	50.0%
Work during labs	50.0%	50.0%

Recommended reading		
	Basic literature	S. Haykin, "Adaptive Filter Theory", Pearson M. I. Skolnik, "Introduction to Radar Systems", McGraw-Hill S. Mallat, "A Wavelet Tour of Signal Processing", Academic Press
	Supplementary literature	No guidelines
	eResources addresses	

Example issues/ example questions/ tasks being completed	Analysis of the effect of covariance matrix parameters on the effectiveness of adaptive filtering in object tracking systems. Design of a radar signal detection algorithm using the CFAR method and evaluation of its effectiveness under low SNR conditions.
Practical activites within the subject	Not applicable