GDAŃSK UNIVERSITY OF TECHNOLOGY

Subject card

Subject name and code	Nonlinear Data Analysis Methods, PG_00069468					
Field of study	Mathematics					
Date of commencement of studies	October 2025		Academic year of realisation of subject		2026/2027	
Education level	second-cycle studies		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	2		Language of instruction		Polish	
Semester of study	3		ECTS credits		4.0	
Learning profile	general academic profile		Assessment form		assessment	
Conducting unit	Divison of Differential Equations and Applications of Mathematics -> Institute of Applied Mathematics -> Faculty of Applied Physics and Mathematics -> Faculties of Gdańsk University of Technology					
Name and surname of lecturer (lecturers)	Subject supervisor	dr inż. Justyna Signerska-Rynkowska				
	Teachers	dr inż. Justyna Signerska-Rynkowska				

Lesson types	Lesson type	Lecture	Tutorial	Laboratory	Project	Seminar	SUM
	Number of study hours	30.0	0.0	30.0	0.0	0.0	60
	E-learning hours included: 0.0						
	eNauczanie source address: https://enauczanie.pg.edu.pl/moodle/course/view.php?id=45943						
	Additional information: In the preparation of activities on the eNauczanie platform, I used the competences obtained during the course "Tworzenie zasobów edukacyjnych prowadzenie zajęć na uczelnianej platformie eNauczanie" within the POWER 3.4 program implemented at the Gdańsk University of Technology.						

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	5.0	35.0	100

Subject objectives	The use of mathematical tools for selected methods of data and time series analysis; increasing awareness about the limitations of linear methods and the problem of proper selection of non-linear methods; solving theoretical and implementation problems; ability to use advanced mathematical methods for data analysis and modeling of phenomena from other fields of science and engineering.

Learning outcomes	<table><tr><th>Course outcome</th><th>Subject outcome</th><th>Method of verification</th></tr><tr><td>[K7_U09] constructs mathematical models used in specific advanced applications of mathematics, can use stochastic processes as a tool for modeling phenomena and analyzing their evolution,constructs mathematical models used in specific advanced applications of mathematics, uses stochastic processes as a tool for modeling phenomena and analyzing their evolution, recognizes mathematical structures in physical theories</td><td>discusses various types of mathematical models describing phenomena and relationships in other fields of science (medicine, biology, chemistry, physics, technical sciences); knows the basics and paradigms of mathematical modeling; analyzes the obtained models in depth using knowledge from various branches of mathematics (dynamical systems, chaos theory, stochastic processes, statistics); applies mathematical models to forecast and classify data</td><td>[SU4] Assessment of ability to use methods and tools [SU2] Assessment of ability to analyse information [SU1] Assessment of task fulfilment</td></tr><tr><td>[K7_U10] understands the mathematical foundations of the analysis of algorithms and computational processes, constructs algorithms with good numerical properties, used to solve typical and unusual mathematical problems</td><td>constructs and implements algorithms and programs useful in nonlinear data analysis in a selected programming language, verifies their correctness and effectiveness, analyzes the obtained results</td><td>[SU4] Assessment of ability to use methods and tools [SU3] Assessment of ability to use knowledge gained from the subject [SU1] Assessment of task fulfilment</td></tr><tr><td>[K7_W05] demonstrates knowledge the numerical methods used to find approximate solutions to mathematical problems posed by applied fields</td><td>skillfully synthesizes elements from various branches of mathematics to solve problems in contemporary data analysis</td><td>[SW1] Assessment of factual knowledge</td></tr></table>
Subject contents	Course content – lecture The notions of signal, time series, data predicting. Mathematical models and their identifications. Stationarity. Discrete- and continuous time Fourier transform. Power spectrum. Selected linear methods of data analysis: linear regression, least squares method and its variants (weighted and generalized least squares method). Non-linear regression. Logistic regression. Predicting and data classification with the use of logistic regression. Fundamentals of Dynamical Systems Theory (phase space, stability, limit cycle, attractor, Poincaré return map). Deterministic chaos: Henon map and Lorenz system, strange attractors, box dimension (demonstratively). Phase space reconstruction (method of delays, false nearest neighbours, return map). Instability: sensitivity to initial conditions and Lyapunov exponents. Information and Shannon entropy. Rényi entropy. Kolmogorov-Sinai entropy. Whitney's and Takens' embedding theorems.
Prerequisites and co-requisites	Knowledge from the courses: Mathematical Analysis, Linear Algebra, Differential Equations. Additionally: selected concepts of Functional Analysis, Stochastic Processes, Statistics, Dynamical Systems, Ergodic Theory

Assessment methods and criteria	<table><tr><th>Subject passing criteria</th><th>Passing threshold</th><th>Percentage of the final grade</th></tr><tr><td>Completion of the lecture classes (Lesson, Quiz, Tasks on eNauczanie and 2h final test)</td><td>50.0%</td><td>50.0%</td></tr><tr><td>Completion of the laboratory classes (tasks solving/programs writing, 2 h final test)</td><td>50.0%</td><td>50.0%</td></tr></table>

Recommended reading	Basic literature	A. Muciek, *Wyznaczanie modeli matematycznych z danych eksperymentalnych*, Oficyna Wydawnicza Politechniki Wrocławskiej, 2012 Y. C. Eldar, *Sampling theory: Beyond Bandlimited Systems,* Cambridge University Press, 2015 J. D. Cryer, K.-S. Chan. *Time Series Analysis.With Applications in R.* Springer Texts in Statistics. Springer-Verlag New York., 2008. H. Kantz, T. Schreiber. *Nonlinear Time Series Analysis*. Cambridge: Cambridge University Press, 2003.
	Supplementary literature	D.W.Hosmer, S.Lemeshow, *Applied logistic regression*, Wiley series in probability and mathematical statistics. Wyd. 2, John Wiley & Sons, 2004 R.G. Andrzejak, *Nonlinear time series analysis in a nutshell*. Osorio et al. (eds.) Epilepsy: The Intersection of Neurosciences, Biology, Mathematics, Engineering and Physics, 125-138, 2011. D. J.C. MacKay. *Information theory, inference and learning algorithms.* Cambridge university press, 2003.
	eResources addresses	
Example issues/ example questions/ tasks being completed	Write a program that determines the formula for a continuous-time Fourier transform CTFT of signal x (t). Without using a ready-made function, write a program that draws a step-by-step linear regression model for a dataset using the classical least squares method. Determine the Shannon entropy of the given ECG time series. Discuss the method of logistic regression and its assumptions. Create two time series (one stochastic and the other one deterministic based on nonlinear observable composed with the Ulam function) and compare their mean, variance and power spectrum.	
Practical activites within the subject	Not applicable	

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