GDAŃSK UNIVERSITY OF TECHNOLOGY

Subject card

Subject name and code	Nonlinear Data Analysis Methods, PG_00050486		
Field of study	Mathematics		
Date of commencement of studies	October 2023	Academic year of realisation of subject	2024/2025
Education level	second-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	2	Language of instruction	Polish
Semester of study	3	ECTS credits	5.0
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		
Name and surname of lecturer (lecturers)	Subject supervisor	dr inż. Justyna Signerska-Rynkowska	
	Teachers	dr inż. Justyna Signerska-Rynkowska mgr inż. Katarzyna Tessmer	

Lesson types and methods of instruction

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

Address on the e-learning platform: https://enauczanie.pg.edu.pl/moodle/course/view.php?id=6026

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	60.0	125

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

Course outcome	Subject outcome	Method of verification
[K7_U13] Understands the mathematical foundations of the analysis of algorithms and computational processes, can construct algorithms with good numerical properties, used to solve typical and unusual mathematical problems.	constructs and implements algorithms and programs useful in nonlinear data analysis in selected programming languages, verifies their correctness and effectiveness, analyses the obtained results	[SU1] Assessment of task fulfilment [SU3] Assessment of ability to use knowledge gained from the subject [SU4] Assessment of ability to use methods and tools
[K7_W05] Has enhanced knowledge of a selected branch of mathematics: knows most classical definitions and theorems and their proofs, Understands problems being examined, Knows relations between problems from particular field with other branches of mathematics, theoretical and applied	skillfully synthethizes elements of various branches of mathematics to solve problems of modern data analysis	[SW1] Assessment of factual knowledge
[K7_U11] Can construct mathematical models used in specific advanced applications of mathematics, can use stochastic processes as a tool for modeling phenomena and analyzing their evolution.	discusses various classes of mathematical models describing phenomena and relationships in other fields of science (medicine, biology, chemistry, technical sciences); knows the basics and paradigms of mathematical modeling; thoroughly analyzes the obtained models using knowledge from various branches of mathematics (dynamical systems; chaos theory, stochastic processes, statistics); uses mathematical models for forecasting and data classification	[SU1] Assessment of task fulfilment [SU2] Assessment of ability to analyse information [SU4] Assessment of ability to use methods and tools

Subject contents

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

<table>
<tr><td>Assessment methods and criteria</td><td colspan="2"><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>40.0%</td></tr>
<tr><td>Completion of the laboratory classes (tasks solving/programs writing, 2 h final test)</td><td>50.0%</td><td>60.0%</td></tr>
</table></td></tr>
<tr><td rowspan="3">Recommended reading</td><td>Basic literature</td><td>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.</td></tr>
<tr><td>Supplementary literature</td><td>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.</td></tr>
<tr><td>eResources addresses</td><td>Adresy na platformie eNauczanie:
Metody nieliniowej analizy danych 2024/25 - Moodle ID: 14609
https://enauczanie.pg.edu.pl/moodle/course/view.php?id=14609</td></tr>
<tr><td>Example issues/ example questions/ tasks being completed</td><td colspan="2">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.</td></tr>
<tr><td>Work placement</td><td colspan="2">Not applicable</td></tr>
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