

## 。 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<br>Subject group related to scientific<br>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   | t          | Seminar | SUM |
|  | Number of study<br>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:<br>In the preparation of activities on the eNauczanie platform, I used the competences obtained during the<br>course "Tworzenie zasobów edukacyjnych prowadzenie zajęć na uczelnianej platformie eNauczanie" within<br>the POWER 3.4 program implemented at the Gdańsk University of Technology.   |  |   |                                     |   |            |         |     |
| Learning activity<br>and number of study hours | Learning activity  | Participation in didactic<br>classes included in study<br>plan |   | Participation in consultation hours |   | Self-study |         | SUM |
|  | Number of study<br>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<br>mathematical foundations of the<br>analysis of<br>algorithms and computational<br>processes, can construct<br>algorithms with<br>good numerical properties, used<br>to solve typical and unusual<br>mathematical problems.  | constructs and implements<br>algorithms and programs useful in<br>nonlinear data analysis in selected<br>programming languages, verifies<br>their correctness and<br>effectiveness, analyses the<br>obtained results   | [SU1] Assessment of task<br>fulfilment<br>[SU3] Assessment of ability to<br>use knowledge gained from the<br>subject<br>[SU4] Assessment of ability to<br>use methods and tools |  |  |  |  |
|                                    | [K7_W05] Has enhanced<br>knowledge of a selected branch of<br>mathematics: knows most<br>classical definitions and theorems<br>and their proofs, Understands<br>problems being examined, Knows<br>relations between problems from<br>particular field with other branches<br>of mathematics, theoretical and<br>applied | skillfully synthethizes elements of<br>various branches of mathematics<br>to solve problems of modern data<br>analysis   | [SW1] Assessment of factual knowledge   |  |  |  |  |
|                                    | [K7_U11] Can construct<br>mathematical models used in<br>specific advanced<br>applications of mathematics, can<br>use stochastic processes as a tool<br>for<br>modeling phenomena and<br>analyzing their evolution.   | discusses various classes of<br>mathematical models describing<br>phenomena and relationships in<br>other fields of science (medicine,<br>biology, chemistry, technical<br>sciences); knows the basics and<br>paradigms of mathematical<br>modeling; thoroughly analyzes the<br>obtained models using knowledge<br>from various branches of<br>mathematics (dynamical systems;<br>chaos theory, stochastic<br>processes, statistics); uses<br>mathematical models for<br>forecasting and data classification | [SU1] Assessment of task<br>fulfilment<br>[SU2] Assessment of ability to<br>analyse information<br>[SU4] Assessment of ability to<br>use methods and tools                      |  |  |  |  |
| Subject contents                   | The notions of signal, time series, da  | ata predicting. Mathematical models  | and their identifications.  |  |  |  |  |
|                                    | Stationarity. Discrete- and continuous time Fourier transform. Power spectrum.<br>Selected linear methods of data analysis: linear regression, least squares method and its variants (weighted<br>and generalized least squares method).  |  |   |  |  |  |  |
|                                    | regression. Logistic regression. Predicting and data classification with the use of logistic  |  |   |  |  |  |  |
|                                    | 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<br>and co-requisites | Knowledge from the courses: Mathe   | matical Analysis, Linear Algebra, Dif  | erential Equations.   |  |  |  |  |
|                                    | Additionally: selected concepts of Fu<br>Ergodic Theory   | unctional Analysis, Stochastic Proces  | ses, Statistics, Dynamical Systems,   |  |  |  |  |

| Assessment methods   | Subject passing criteria   | Passing threshold   | Percentage of the final grade |  |  |
|--|--|---|-------------------------------|--|--|
| and criteria   | Completion of the lecture classes<br>(Lesson, Quiz, Tasks on<br>eNauczanie and 2h final test)  | 50.0%   | 40.0%                         |  |  |
|  | Completion of the laboratory<br>classes (tasks solving/programs<br>writing, 2 h final test)  | 50.0%   | 60.0%                         |  |  |
| Recommended reading  | Basic literature A. Muciek, Wyznaczanie modeli matematycznych z danych eksperymentalnych, Oficyna Wydawnicza Politechniki Wrocławskie 2012   |   |                               |  |  |
|  |  | Y. C. Eldar, Sampling theory: Beyond Bandlimited Systems, Cambridge University Press, 2015  |                               |  |  |
|  |  | J. D. Cryer, KS. Chan. <i>Time Series Analysis.With Applications in R.</i><br>Springer Texts in Statistics. Springer-Verlag New York., 2008.  |                               |  |  |
|  |  | H. Kantz, T. Schreiber. <i>Nonlinear Time Series Analysis</i> . Cambridge Cambridge University Press, 2003.   |                               |  |  |
|  | Supplementary literature   | ).W.Hosmer, S.Lemeshow, <i>Applied logistic regression</i> , Wiley series in<br>robability and mathematical statistics. Wyd. 2, John Wiley & Sons,<br>2004  |                               |  |  |
|  |  | R.G. Andrzejak, <i>Nonlinear time series analysis in a nutshell</i> . Osorio et al. (eds.) Epilepsy: The Intersection of Neurosciences, Biology, Mathematics, Engineering and Physics, 125-138, 2011. |                               |  |  |
|  |  | D. J.C. MacKay. <i>Information theory, inference and learning algorithms</i> . Cambridge university press, 2003.  |                               |  |  |
|  | eResources addresses   | Adresy na platformie eNauczanie:<br>Metody nieliniowej analizy danych 2024/25 - Moodle ID: 14609<br>https://enauczanie.pg.edu.pl/moodle/course/view.php?id=14609                                      |                               |  |  |
| Example issues/<br>example questions/<br>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. |   |                               |  |  |
| Work placement   | Not applicable   |   |                               |  |  |

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