GDAŃSK UNIVERSITY OF TECHNOLOGY

Subject card

Subject name and code	Topological data analysis, PG_00051783		
Field of study	Mathematics		
Date of commencement of studies	October 2022	Academic year of realisation of subject	2023/2024
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	4	ECTS credits	3.0
Learning profile	general academic profile	Assessment form	assessment
Conducting unit	Zakład Równań Różniczkowych i Zastosowań Matematyki -> Instytut Matematyki Stosowanej -> Faculty of Applied Physics and Mathematics		
Name and surname of lecturer (lecturers)	Subject supervisor	dr hab. Paweł Pilarczyk	
	Teachers	Michał Palczewski dr hab. Paweł Pilarczyk	

Lesson types and methods of instruction	Lesson type	Lecture	Tutorial	Laboratory	Project	Seminar	SUM
	Number of study hours	30.0	0.0	15.0	15.0	0.0	60
	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	60	5.0	10.0	75

Subject objectives

Getting familiar with mathematical foundations and software techniques for computational topology and topological data analysis, as well as with examples of applications in selected areas of science.

Learning outcomes

Course outcome	Subject outcome	Method of verification
K7_U13	Can apply selected software tools for topological computations. Can describe and explain selected topics and methods of computational topology and data analysis.	[SU5] Assessment of ability to present the results of task [SU1] Assessment of task fulfilment
K7_W11	Knows selected terminology and mathematical foundations of computational topology and topological data analysis.	[SW1] Assessment of factual knowledge

Subject contents	Lecture: Basic ideas of computational topology. Simplicial and cubical complexes. Definition and algorithms for the computation of homology. Homomorphisms induced in homology. Čech complexes and Vietoris-Rips complexes. Persistent homology and algorithms for its computation. Persistence diagrams. Software for the computation of simplicial and cubical homology, as well as persistent homology. Distance between persistence diagrams. Persistence landscapes, silhouettes, and images. Topological analysis of time series. Mapper - a topological algorithm for data exploration. Topological analysis of dynamical systems. Laboratory: The CHomP software for homology computation. Comparison of homology with integer coefficients against homology with coefficients in the field Z_p. Approximation of subsets of R^n with cubical sets. Software for persistent homology computation, including Dionysus, Ripser, Persim. Barcodes. Practical computation of Gromov-Hausdorff distance. Computation of the bottleneck distance and the Wasserstein distance between persistence diagrams. Practical construction of persistence landscapes. Topological data analysis with the GUDHI software. Project: Becoming familiar with specific methods and applications of topological data analysis, based upon selected scientific literature (papers in international academic journals), for example, regarding topological analysis of biological data.
Prerequisites and co-requisites	Ability to write simple computer programs in Python and in R. Basic knowledge of algebraic topology. Familiarity with basic terminology and methods in data science.
Assessment methods and criteria	

Subject passing criteria	Passing threshold	Percentage of the final grade
group projects	60.0%	30.0%
10-minute-long quizzes during lectures	60.0%	40.0%
laboratory exercises every week	60.0%	30.0%

Recommended reading	Basic literature	T. Kaczynski, K. Mischaikow, M. Mrozek. Computational homology. Applied Mathematical Sciences, vol 157. Springer-Verlag, New York 2004. Frédéric Chazal, Bertrand Michel: An introduction to Topological Data Analysis: fundamental and practical aspects for data scientists. https://arxiv.org/abs/1710.04019
	Supplementary literature	C.J.A. Delfinado, H. Edelsbrunner, An incremental algorithm for Betti numbers of simplicial complexes on the 3-sphere, Computer Aided Geometric Design, Volume 12, Issue 7 (1995), 771-784, DOI: 10.1016/0167-8396(95)00016-Y T. Kaczyński, M. Mrozek, M. Ślusarek, Homology computation by reduction of chain complexes, Computers & Mathematics with Applications 35(4):59-70 (1998), DOI: 10.1016/S0898-1221(97)00289-7
	eResources addresses	Podstawowe https://people.clas.ufl.edu/peterbubenik/intro-to-tda/ - Peter Bubenik. Topological Data Analysis. A selection of introductory materials. (Accessed on February 2, 2021.) Adresy na platformie eNauczanie: Topologiczna analiza danych 2024 - Moodle ID: 31166 https://enauczanie.pg.edu.pl/moodle/course/view.php?id=31166

Example issues/ example questions/ tasks being completed	Definition of elementary cubes, cubical sets, cubical chain complexes, and cubical homology. What is the homology of two torii that touch each other in one point? Definition of persistent homology of a point cloud in R^n. How does one define the distance between two persistence diagrams?
Work placement	Not applicable