



## Subject card

Subject name and code	Topological data analysis, PG_00070311						
Field of study	Mathematics						
Date of commencement of studies	October 2024	Academic year of realisation of subject			2025/2026		
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	4	ECTS credits			2.0		
Learning profile	general academic profile	Assessment form			assessment		
Conducting unit	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 hab. Paweł Pilarczyk					
	Teachers	dr hab. Paweł Pilarczyk					
Lesson types	Lesson type	Lecture	Tutorial	Laboratory	Project	Seminar	SUM
	Number of study hours	30.0	0.0	15.0	0.0	15.0	60
	E-learning hours included: 0.0						
	eNauczanie source address: <a href="https://enauczanie.pg.edu.pl/moodle/course/view.php?id=46660">https://enauczanie.pg.edu.pl/moodle/course/view.php?id=46660</a> Moodle ID: 46660 Topologiczna analiza danych 2026 <a href="https://enauczanie.pg.edu.pl/moodle/course/view.php?id=46660">https://enauczanie.pg.edu.pl/moodle/course/view.php?id=46660</a>						
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	0.0	0.0	60		
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_W06] analyzes the mathematical foundations of information theory, the theory of algorithms and cryptography and their practical applications, i.a. in programming and computer science.	Knows selected terminology and mathematical foundations of computational topology and topological data analysis.			[SW1] Assessment of factual knowledge [SW3] Assessment of knowledge contained in written work and projects		
	[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	Can apply selected software tools for topological computations. Can describe and explain selected topics and methods of computational topology and data analysis.			[SU1] Assessment of task fulfilment [SU2] Assessment of ability to analyse information		

Subject contents	<p>Course content – lecture</p> <p>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.</p>		
	<p>Course content – laboratory</p> <p>The CHomP software for homology computation. Comparison of homology with integer coefficients against homology with coefficients in the field <math>\mathbb{Z}_p</math>. Approximation of subsets of <math>\mathbb{R}^n</math> 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.</p>		
	<p>Course content – seminar</p> <p>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.</p>		
Prerequisites and co-requisites	Ability to write 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
	laboratory exercises every week	60.0%	30.0%
	10-minute-long quizzes during lectures	60.0%	40.0%
	presentation at the seminar	60.0%	30.0%
Recommended reading	Basic literature	Frédéric Chazal, Bertrand Michel: An introduction to Topological Data Analysis: fundamental and practical aspects for data scientists. Frontiers in Artificial Intelligence 4 (2021), <a href="https://doi.org/10.3389/frai.2021.667963">https://doi.org/10.3389/frai.2021.667963</a>	
	Supplementary literature	T. Kaczynski, K. Mischaikow, M. Mrozek. Computational homology. Applied Mathematical Sciences, vol 157. Springer-Verlag, New York 2004.	
		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			
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 $\mathbb{R}^n$ .		
	How does one define the distance between two persistence diagrams?		
Practical activities within the subject	Not applicable		

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