GDAŃSK UNIVERSITY OF TECHNOLOGY

Subject card

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|---|---|---|---|
| Subject name and code | Topological data analysis, PG_00051783 | | |
| 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 | |
| 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 | 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 hab. Paweł Pilarczyk | |
| | Teachers | 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 | 0.0 | 15.0 | 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 |
|---|---|---|

**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.

<table>
<tr><td>Prerequisites and co-requisites</td><td>Ability to write simple computer programs in Python and in R.<br><br>Basic knowledge of algebraic topology.<br><br>Familiarity with basic terminology and methods in data science.</td></tr>
<tr><td>Assessment methods and criteria</td><td>
<table>
<tr><th>Subject passing criteria</th><th>Passing threshold</th><th>Percentage of the final grade</th></tr>
<tr><td>laboratory exercises every week</td><td>60.0%</td><td>30.0%</td></tr>
<tr><td>10-minute-long quizzes during lectures</td><td>60.0%</td><td>40.0%</td></tr>
<tr><td>group projects</td><td>60.0%</td><td>30.0%</td></tr>
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<tr><td>Recommended reading</td><td>
<table>
<tr><td>Basic literature</td><td>T. Kaczynski, K. Mischaikow, M. Mrozek. Computational homology. Applied Mathematical Sciences, vol 157. Springer-Verlag, New York 2004.<br><br>Frédéric Chazal, Bertrand Michel: An introduction to Topological Data Analysis: fundamental and practical aspects for data scientists. https://arxiv.org/abs/1710.04019</td></tr>
<tr><td>Supplementary literature</td><td>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<br><br>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</td></tr>
<tr><td>eResources addresses</td><td>Podstawowe<br>https://people.clas.ufl.edu/peterbubenik/intro-to-tda/ - Peter Bubenik. Topological Data Analysis. A selection of introductory materials. (Accessed on February 2, 2021.)<br>Adresy na platformie eNauczanie:</td></tr>
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<tr><td>Example issues/ example questions/ tasks being completed</td><td>Definition of elementary cubes, cubical sets, cubical chain complexes, and cubical homology.<br><br>What is the homology of two torii that touch each other in one point?<br><br>Definition of persistent homology of a point cloud in R^n.<br><br>How does one define the distance between two persistence diagrams?</td></tr>
<tr><td>Work placement</td><td>Not applicable</td></tr>
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