Syllabus
Topological Data Analysis, 6hp

Issued by the WASP graduate school management group 2022 03 08.

Main field of study

AI/mlx, AI/math

Course level

PhD student course

Course offered for

PhD Students in the WASP graduate school

Entry requirements

The participants are assumed to have a background in mathematics corresponding to the contents of the WASP-course "Mathematics for Machine Learning" and especially they should have completed a course in linear algebra.

Intended learning outcomes

After completing the course, students should be able to

- convert data into a format that is suitable for TDA (Topological Data Analysis) algorithms.
- extract topological invariants from data using appropriate TDA software and methodologies
- make conclusions and discuss the outcome of a TDA analysis
- be able to reason about the algorithmic complexity of TDA and its constructions such as simplicial complexes and matrix reduction algorithms.
- be able to describe how TDA methods relate to current research topics in machine learning and computational geometry

Course content

In this course the technical tool we introduce to describe geometry is based on **homology**. The main aim of the course is to explain how versatile this tool is and how to use this versatility to give a machine the ability to learn to sense geometry.

Technical tool

Homology, the central theme of the 20th century geometry, has been particularly useful for studying spaces with controllable cell decompositions such as Grassmann varieties. During the last decade there has been an explosion of applications ranging from neuroscience to vehicle tracking, protein structure analysis and the nano characterization of materials, testifying to the usefulness of homology to describe also spaces related to data sets. One might ask: why homology? Often due to heterogeneity or the presence of noise, it is very hard to understand our data. In these cases rather than trying to fit the data with complicated models a good strategy is to first investigate the shape properties of such data. Here homology comes into play.

Learning

We explain how to use homology to convert geometry of datasets into features suitable for statistical analysis and machine learning. It is a process that translates spacial and geometrical information into information that can be analysed through more basic operations such as counting and integration. Furthermore we provide an entire space of such translations.

Teaching and working methods

The course will be held via lectures and exercises with a final pass/fail group project at the end. The course includes three 2-day meetings with intense teaching on-site. Lectures focus on introducing the required mathematical and technical tools for TDA, discussing computational complexity, software and the relation of TDA to current research topics in Machine Learning and Computational Geometry research.

Examination

The course is examined through a group project at the end of the course where students explore TDA applications from an algorithmic, mathematical or real-world use case point of view.

Grades

Fail or Pass