Topological Data Analysis for Spatial Data

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Scientific Visualization

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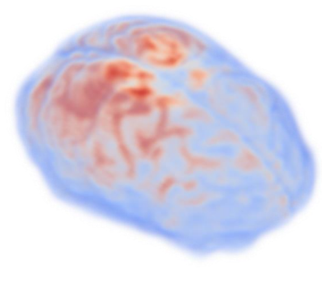
Motivation & Highlights

Nowadays, we often encounter challenging datasets that contain noise, high dimensionality, and complexity. Overreliance on measurement makes standard tools less informative for challenging data. More informative methods are required that should not rely on the precise measurements but rather rely on the notion of proximity and able to extract underlying shape of data. Topological approaches provide geometrically invariant descriptors that help the user to understand and get insight into their data.

The goal of my research is to develop methods for identification, extraction, tracking, and comparison of topological descriptors in the time-varying data. In addition, the focus is to integrate analysis pipeline in a user-friendly dashboard containing interactive linked visual components, enabling users to interact and make sense of their data.

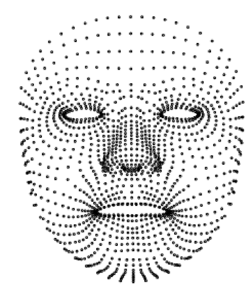
Data Types

Topological methods can work on many types of data, from unstructured point clouds to 3D volumes. These methods require a filtration strategy, which is defined either by a distance metric or a scalar function, depending on the type of problem.

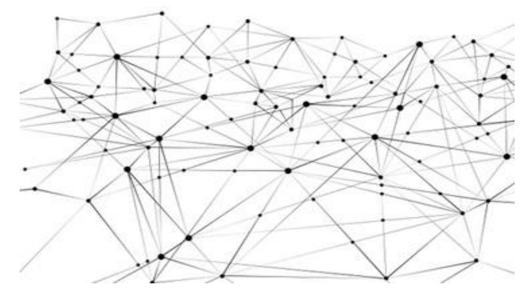


3D Volume Data (MRI)

Images



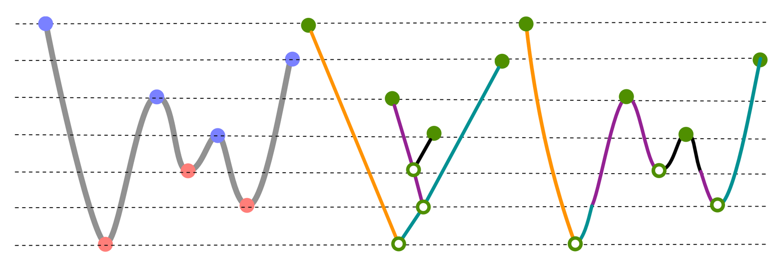
Point cloud



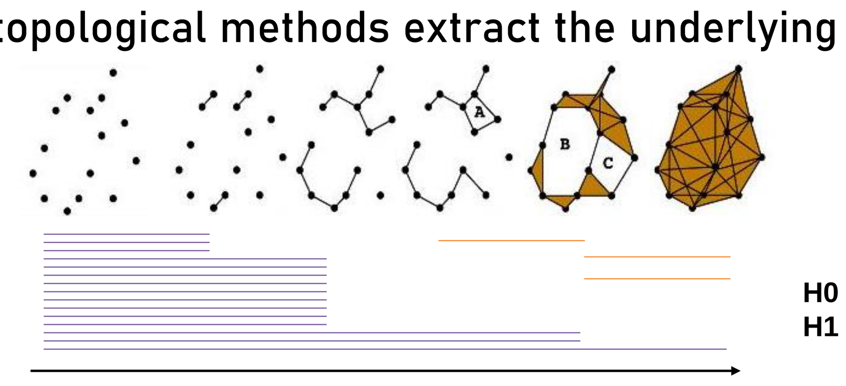
Graphs

Topological Features and Data Summary

Given an input data and a filtration strategy, topological methods extract the underlying shape of the data.

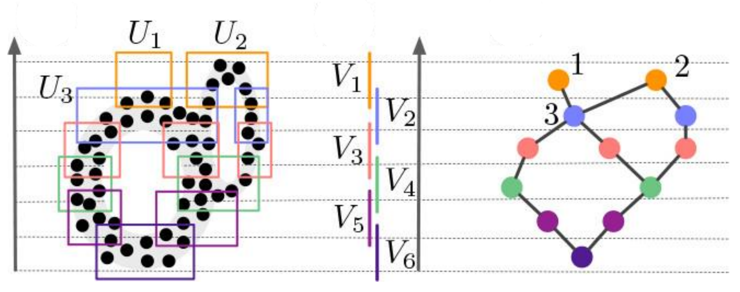


Scalar function | Merge Tree | Topological Segmentation

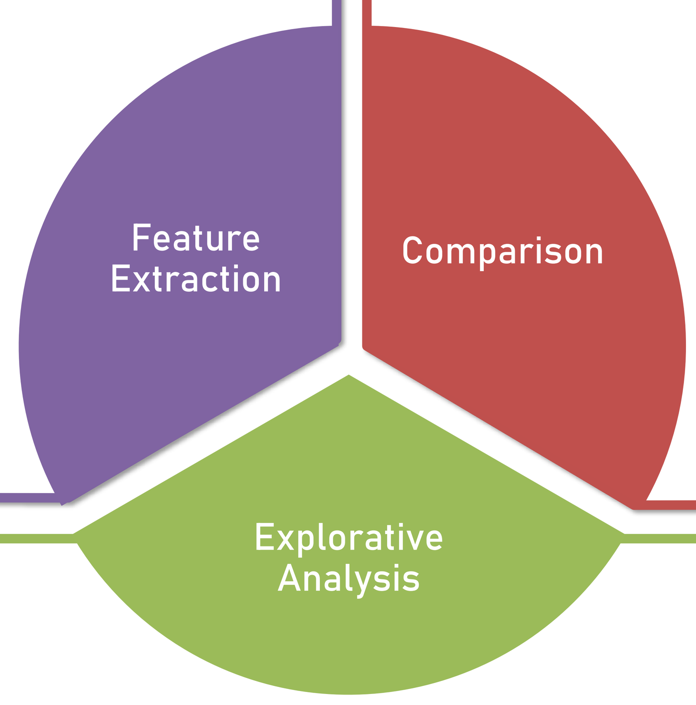


Filtration on Point cloud

Persistent homology for data defined on a continuous domain. Using sublevel set filtration, we can obtain an abstraction illustrating the hierarchy of segmentation.

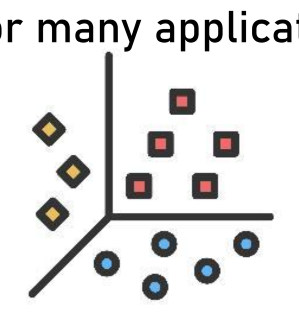


Mapper graph: Given a point cloud, filtration and clustering, the mapper graph transform the input point cloud into a combinatorial object.

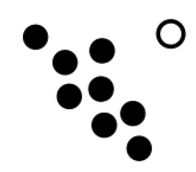


Comparative Measure

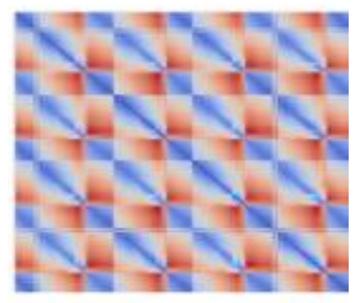
Comparing two datasets based on their topological descriptor is non-trivial and it is crucial for many application.



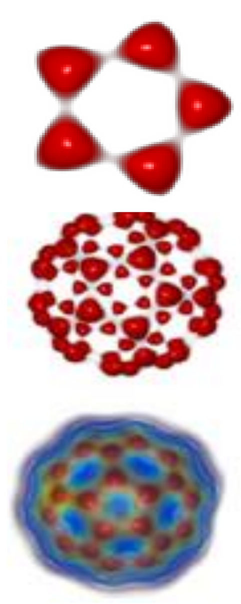
Clustering



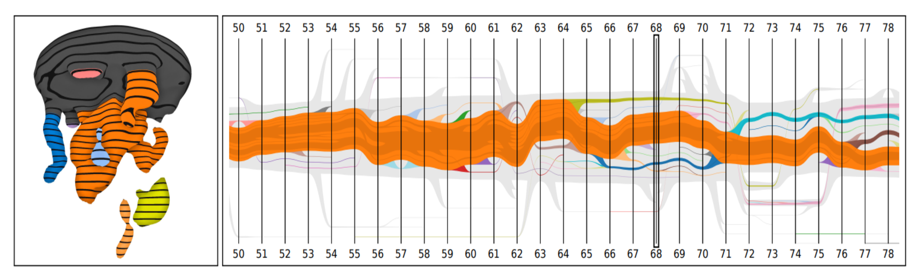
Outlier Detection



Periodicity detection

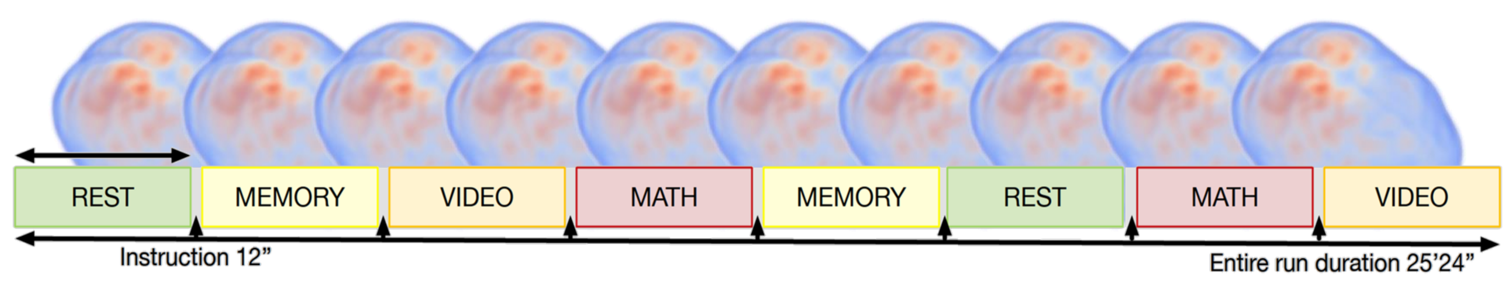


Self similarity



Lukasczyk et al. 2017, Tracking

Analysis of Dynamic fMRI Data

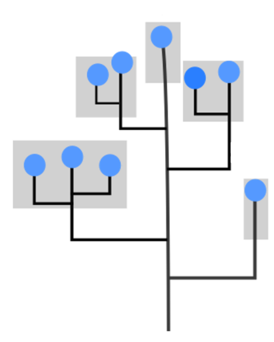


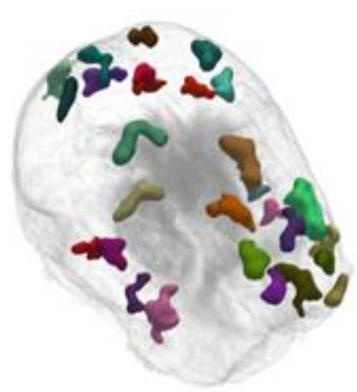
Data & Challenges

This project was about the analysis of the dynamic functional MRI data. Functional MRI dataset is challenging and inherently noisy. The underlying activity signal is polluted from man sources such as psychological & physiological noise, noise from scanner.

Activation region extraction

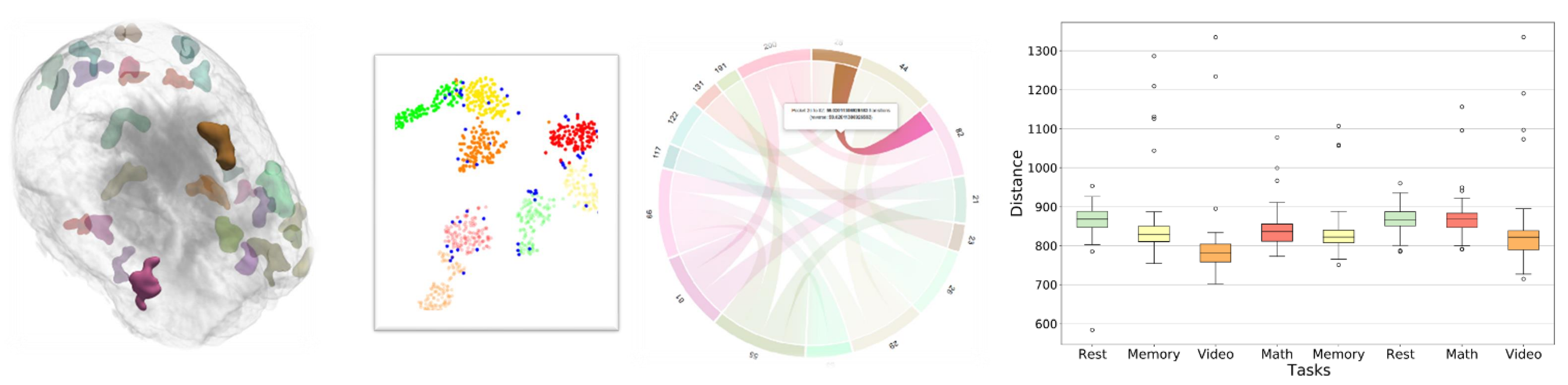
The activation regions in the fMRI data can be extracted by utilizing merge trees. Each branch in the tree defines a region that corresponds to the activity in the brain. The entire tree then provides the topological segmentation of the underlying domain.





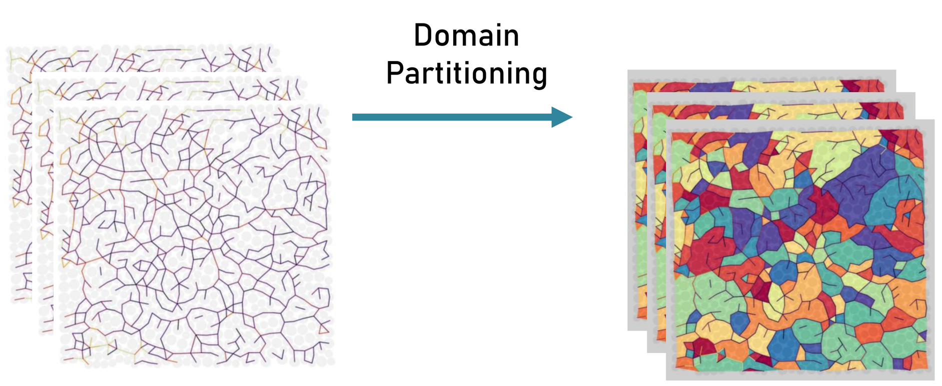
Activation region extraction

Illustration of the main components used to explore the time-varying brain activity in both temporal and spatial aspect.



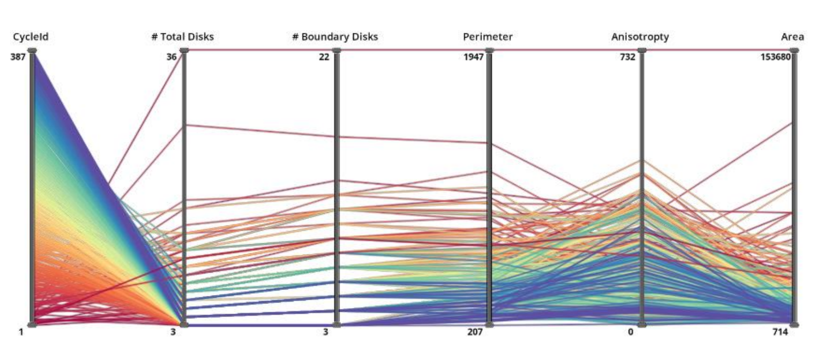
Spatially Embedded Graphs in Granular Materials

This project is about the analysis of granular materials such as sand, gravel grains, powder etc. We explore the properties of these materials through analyzing the underlying contact network.



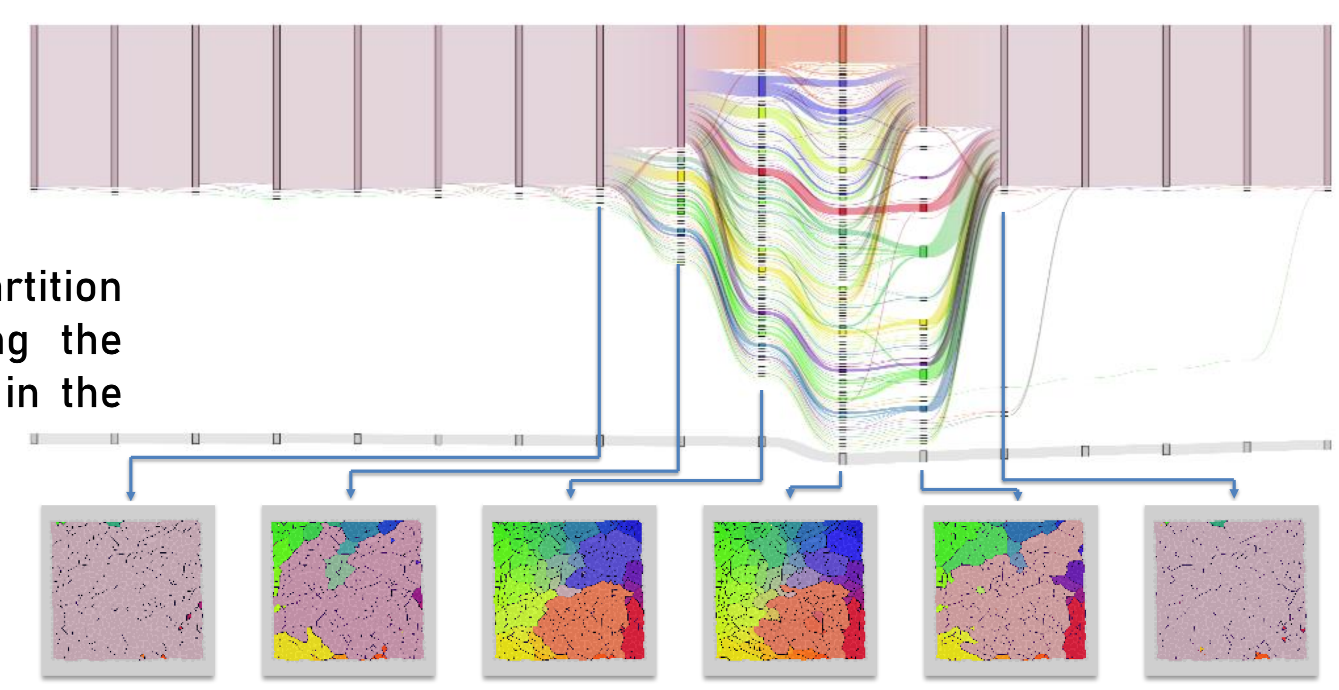
Statistical properties

We extract multiscale cycle within these network. These cycles defines the mesoscale. The properties of these cycles at multiple scale can be visualized as parallel coordinate plot.



Tracking

Visualization of partition tracking illustrating the jamming behavior in the materials.



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