An Introduction to Applied Topology Software

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An Introduction to Applied Topology Software

Part I: Online networking opportunities

Part II: Examples for today’s coding groups

Part III: Overview of software options
Where can I find resources if I am interested in applied topology?

- You may be interested in the **Applied Algebraic Topology Research Network**. Become a member to receive email invites to the online research seminars. Recorded talks are available at the **YouTube Channel**. There is also a **forum**.
- Another source of applied topology news is **appliedtopology.org**.
- A second online research seminar is **GEOTOP-A: Applications of Geometry and Topology**.
- Mailing lists with announcements in applied topology include **WinCompTop** and **ALGTOP-L**.
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Examples using Ripser-live in your html browser

https://github.com/henryadams/Charleston-TDA-ML

- Examples using Ripser-live in your html browser.
- Cyclo-octane molecule
- Primary circle for optical images
- Three circle model, space of regular pentagons
Cyclo-Octane \((C_8H_{16})\) data

Non-Manifold Surface Reconstruction from High Dimensional Point Cloud Data by Shawn Martin and Jean-Paul Watson, 2010.
Cyclo-Octane \((\text{C}_8\text{H}_{16})\) data

Non-Manifold Surface Reconstruction from High Dimensional Point Cloud Data by Shawn Martin and Jean-Paul Watson, 2010.
Cyclo-Octane ($C_8H_{16}$) data

Persistence intervals in dimension 0:

Persistence intervals in dimension 1:

Persistence intervals in dimension 2:

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3x3 High-contrast patches from images

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1. Densest patches according to a global estimate
3x3 High-contrast patches from images

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Interpretation: nature prefers linearity
3x3 High-contrast patches from images

2. Densest patches according to an intermediate estimate

Interpretation: nature prefers horizontal and vertical directions
3x3 High-contrast patches from images

3. Densest patches according to a local estimate

Interpretation: nature prefers linear and quadratic patches at all angles

Image credit: https://plus.maths.org/content/imaging-maths-inside-klein-bottle
Equilateral pentagons in the plane

Image credit: Clayton Shonkwiler
Equilateral pentagons in the plane

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Equilateral pentagons in the plane

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The following image of Devanagari script, which is used in India and Nepal, is from wikipedia (https://en.wikipedia.org/wiki/Devanagari). We will use a dataset with 36 different characters.
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What applied topology software options do I have?

This list undoubtably has unintentional omissions; please email Henry with updates to this list!

This list was originally created to accompany the tutorial https://github.com/henryadams/Charleston-TDA-ML for the NSF-CBMS Conference and Software Day on Topological Methods in Machine Learning and Artificial Intelligence.
Persistent homology

- **CHomP.** Computational Homology Project. C++; Cubical homology.
- **DIPHA.** A Distributed Persistent Homology Algorithm; C++.
- **Dionysus** and **Dionysus 2.** Dionysus is a C++ library for computing persistent homology, equipped with python bindings. It provides implementations of the following algorithms: persistent (co)homology, vineyards, zigzag persistence, etc.
- **Eirene.** Julia platform for computational topology.
- **Javaplex.** Java and Matlab code, equipped with a tutorial with real-life data examples.
- **GUDHI.** The GUDHI library is a generic open source C++ library, with a Python interface, for Topological Data Analysis (TDA) and Higher Dimensional Geometry Understanding. The library offers state-of-the-art data structures and algorithms to construct simplicial complexes and compute persistent homology. The library comes with data sets, demos, examples and test suites.
- **Perseus.** A C++ software project for the rapid computation of persistent homology. Includes cubical and simplicial complexes.
- **PHAT.** C++ code.
- **R-TDA.** Tools for the statistical analysis of persistent homology and for density clustering. For that, this package provides an R interface for the efficient algorithms of the C++ libraries GUDHI, Dionysus, and PHAT. This package also implements methods for analyzing the statistical significance of persistent homology features.
- **Scikit-TDA.** A home for Topological Data Analysis Python libraries intended for non-topologists. This project aims to provide a curated library of TDA Python tools that are widely usable and easily approachable. Contains Ripser.py as one subcomponent.
- **Ripser:** efficient computation of Vietoris-Rips persistence barcodes. It is possible to run a beginner's version of Ripser in your html browser, for which no installation is required.
- **Rivet.** Extends the usual persistent homology pipeline for topological data analysis to the two-parameter setting.
- **SimBa.** C++ software for approximating Rips filtration persistence via simplicial batch-collapse.
A brief (biased) history of PH softwares


2005 **Plex** V. de Silva, P. Perry, L. Kettner, A. Zomorodian

2011 **JavaPlex** A. Tausz, M. Vejdemo-Johansson, H. Adams

2012 **Perseus** V. Nanda

2013 **PHAT** M. Kerber, J. Reininghaus, U. Bauer, H. Wagner

2014 **DIPHA** M. Kerber, J. Reininghaus, U. Bauer

2014 **GUDHI** C. Maria, J.-D. Boissonnat, M. Glisse, M. Yvinec
Thank you!