

Topics in Topology and Geometry - Projects

A term paper and presentation will form 35% of your final grade. The paper should be around 6-10 pages long, and there is some flexibility as to what you write it on. You can work alone or in teams of two or three, but everyone needs to have their own writeup. You should take care to cite your sources clearly, and write in a way understandable to your classmates. The presentations will be during the last few classes, and so they will need to be fairly short, around 10 minutes. Each team member must take part in the presentation.

There are roughly three possibilities for projects that you should consider doing:

1. *More theoretical.* In this type of project you would go beyond the theory that we are doing in class, and give an exposition of some mathematics related to the subject of the course. Some examples are *Morse theory, singular homology, the Gromov-Hausdorff distance, spectral sequences.*
2. *An application from the literature.* Here you would read a research paper that uses topological data analysis (or other topological ideas) for an applied problem, and write up an exposition of it. Your paper should explain the problem and how topological ideas have been useful in making progress in a way understandable to your classmates. Some examples of papers are:
 - Ahmed, Fasy, Wenk - “Local persistent homology based distance between maps.”, SIGSPATIAL 2014
 - Bendich, Marron, Miller, Pieloch, Skwerer - “Persistent homology analysis of brain artery trees”, Ann. Appl. Stat. 10 (2016) no. 1, 198–218
 - Nicolau, Levine, Carlsson - “Topology based data analysis identifies a subgroup of breast cancers with a unique mutational profile and excellent survival”, PNAS 108 (2011) no. 17, 7265–7270
 - Lee, Pedersen, Mumford - “The nonlinear statistics of high-contrast patches in natural images”, International Journal of Computer Vision 54 (2003), 83–103.

You may also want to look at some surveys to get other ideas (and you can also google for more...):

- Carlsson - “Topology and data”, Bull. Amer. Math. Soc. 46 (2009), 255–308
 - Curto - “What can topology tell us about the neural code?”, Bull. Amer. Math. Soc. 54 (2017), 63–78
3. *Working on your own data.* You should feel free to analyze your own dataset, or a data set available publicly, if there is something you are particularly interested in. This will most likely involve some computer programming skills, but there are several freely available packages

implementing tools from topological data analysis. If you choose this path, you must make sure that you have legal access to the data that you use, and that you are allowed to perform the analysis that you intend. Even if you don't find anything very exciting in your data, you will get a good grade if you explain what you are hoping to find, how TDA can help you with this, what exactly you did, and what more you could do if you wanted to go further.

Projects could be a hybrid of these, e.g. where you find a paper doing some interesting data analysis using topological concepts that go beyond the course (which you can then explain), and you try to apply similar ideas to your own dataset.

Deadlines:

- **March 24** - You should have decided on a project and talked to me about it.
- **April 12** - Rough outline of paper should be ready.
- **May 3** - Term paper is due in class.