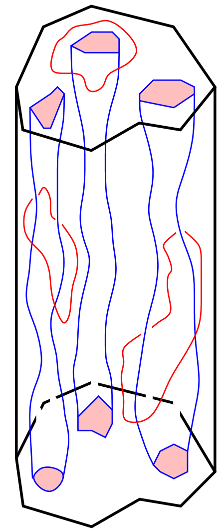
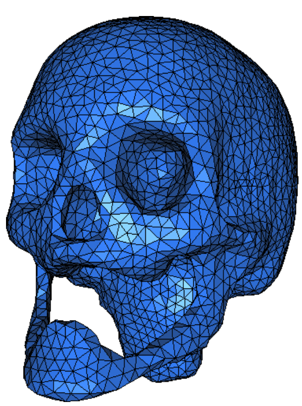
Introduction to Computational Topology (Spring 2016)



Course Number	**Math 574** (Topics Course)
Time	Tue-Thu 16:15–17:30 pm
Location	Jackson 55 (Pullman), VECS 309 (Vancouver)
Instructor	Bala Krishnamoorthy
Office	VSCI 130L
Office Hours	Wed 3–4 pm, Thu 11 am–12 pm **on Skype (ID:wsucomptopo)**
Email	bkrishna@math.wsu.edu
Web page	http://www.wsu.edu/∼kbala/comptopo/
Text	**Class notes and handouts**
References	Edelsbrunner and Harer: Computational Topology ISBN: 0821-84925-5.
	Zomorodian:Topology for Computing ISBN: 0521-13609-1.

Description of the Course

Topology studies how a shape or object is connected. In the past few years, there has been an increased interest in the development and use of topological methods for solving various problems in science and engineering. This new line of study is called **Computational Topology** or **Applied Algebraic Topology**. Computational topology combines topological results with efficient algorithms to analyze data and solve problems in *many* fields, including computer graphics and image analysis, sensor networks, clustering, robotics, genetics, protein biochemistry, geography, and others.



This course will present an **introductory, self-contained overview** of computational topology. There are **no prerequisites**, but mathematical sophistication at the senior undergraduate level and some familiarity with the use of computer packages (e.g., Matlab, Python, etc.) are expected. We will cover basic concepts from a number of areas of mathematics, such as abstract algebra, algebraic topology, and optimization. We will also look at algorithms and data structures, and efficient software for analyzing the topology of point sets and shapes – termed *topological data analysis*, or TDA. The grade will be based on a several homework assignments and a project, which will involve either an implementation or presentation of results from recent research papers.

Individuals with backgrounds in mathematics, engineering, or life sciences with some computational training, will find this class of interest.

Organization and Grading

There will be around eight homework assignments, and a project. The assignments will include mathematical problems as well as ones involving some use of software packages. The project will involve either the implementation and testing of a particular computational topology method, or summarizing at a low level the results of 2–3 related papers. The total score for the course will be calculated using the following weights: homework - 65%, projects - 35%.

Software

We will introduce and use several packages for computational topology such as JavaPlex (for identifying and visualizing structure and topology of data sets). Python or Matlab interfaces are available for many of them, while some of them come with fairly independent standalone implementations (i.e., one would not have to do much coding). For optimization, we will introduce packages such as AMPL, Cplex, and Octave (free alternative to Matla b). The student would be expected to do a limited amount of basic scripting or coding (in Python, Matlab, C/C++, or another language/package).

Topics covered

The following is a rough plan. Based on student interests and course progress, new topics may be included and/or some of the ones listed here may be deleted.

1. Overview, results from topology - 4 lectures
   surfaces, Euler characteristic, homeomorphisms, groups;
2. simplicial complexes - 5 lectures
   Delaunay triangulation, Vietoris-Rips complex, alpha shapes,
   point clouds, simplicial complexes from data;
3. homology - 6 lectures
   homology groups, simplicial homology, relative homology,
   computing homology, data structures and algorithms;
4. optimization - 3 lectures
   linear and integer programming, total unimodularity,
   efficient algorithms, optimality in homology;
5. topological persistence - 10 lectures
   matrix algorithms, stability, barcodes for shape, zigzag persistence; and
6. applications - 2 lectures
   sensor networks, protein structure, CAD,
   clustering, geometric measure theory.

Academic Integrity: Discussion of homework problems with others is allowed, and is encouraged. But each person should hand in his or her own solutions. Plagiarism or cheating will not be tolerated. Such behavior will result in a zero grade for a graded item and possibly a failing grade for the entire course.

Students with Disabilities: Reasonable accommodations are available for students with a documented disability through the Access center. All accommodations must be approved through the WSU Access Center, located in Washington Building 217 in the Pullman campus (phone: (509) 335-3417; email: access.center@wsu.edu) and in the Classroom Building (VCLS) 160 in the Vancouver campus (phone: (360) 546-9138; email: van.access.center@wsu.edu).

WSU Safety Measures: Washington State University is committed to maintaining a safe environment for its faculty, staff, and students. For Pullman, please visit safetyplan.wsu.edu and oem.wsu.edu to access the Campus Safety Plan and emergency information. You should also become familiar with the WSU Alert Site (alert.wsu.edu) where information about emergencies and other issues affecting WSU can be found. In Vancouver, visit the web page for the Campus Safety Plan at vancouver.wsu.edu/safety-plan, which contains a comprehensive listing of university policies, procedures, statistics, and information relating to campus safety, emergency management, and the health and welfare of the campus community.