CMSE 890: Topological Data Analysis
Class: MWF 3:00 - 3:50, 1202 Engineering Building
Credit hours: 3

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Slack:	cmse-courses.slack.com (Click for invite link).
	Join the `#cmse890-tda-f21` channel.
Office Hours and	
Backup Class Zoom Link:	Meeting ID: 932 0324 1319, Passcode: 360178
Office Hours:	Time TBD. Will be held online only. Please join the zoom link posted above.

Course Description:

Topology is the study of shapes. Recently, a great deal of work has gone into the study of using topological methods for problems in science and engineering, particularly in data analysis. This new research topic goes by many names, most often Computational Topology, Applied Topology, or Topological Data Analysis (TDA). We will work with many disparate fields such as algebraic topology, geometry, linear algebra, abstract algebra, algorithms, statistics, and sheaf theory in order to understand recent results in the field. We will study and use efficient software for the computation of things discussed in class, such as persistent homology and Reeb graphs. We will also look at applications in fields such as computer graphics, image analysis, sensor networks, clustering, time series analysis, and genetics.

Prerequisites:

Mathematical prerequisites: Linear algebra. Some familiarity of computer programming with packages such as Python, R, or MATLAB is expected. Individuals with backgrounds in mathematics, engineering, computer science, or other natural sciences with some computational training, will find this class of interest.
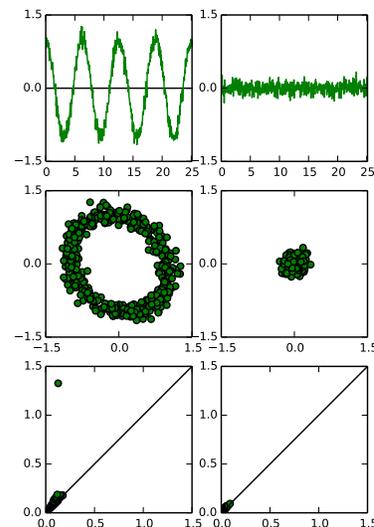
Website:

The D2L website, https://d2l.msu.edu/, has information about the course and any necessary files. Homework assignments and project information will also be posted on D2L. The majority of announcements will come through the Slack channel so be sure to keep up to date with that.

Textbook:

1. *Required:* Tamal K. Dey and Yusu Wang. Computational Topology for Data Analysis, 2021. Available free at https://www.cs.purdue.edu/homes/tamaldey/book/CTDAbook/CTDAbook.html

2. *Recommended:* Herbert Edelsbrunner & John Harer. Computational Topology: An Introduction. American Mathematical Society, 2010.

3. *Recommended:* Munkres, James R. Elements of algebraic topology. Vol. 2. Reading: Addison-Wesley, 1984.

Grading:

- **Reading:** This course will be extremely reading heavy. Since we are looking at state of the art research, this will be a mix of textbook reading and research papers. Other than the textbook, all readings will be posted on blackboard.

- **Homework:** There will be approximately bi-weekly homework sets given which will be turned in for a grade. This homework will be typeset (preferably in LaTeX) or no credit will be given.

  Homeworks are due every other Friday at midnight. Homeworks submitted before midnight Saturday will still be graded with a 5% penalty. Homeworks submitted before midnight Sunday will still be graded with a 15% penalty. After midnight Sunday, no credit will be given, but see the dropped grades policy above.

  The material presented draws from many disparate backgrounds, and it is highly unlikely any one student will have experience with all of it. To that end, I encourage students to work together, discuss the problems, and teach each other while struggling together. My collaboration policy is as follows.

  - I **do** assume you will talk to each other to work on things.
  - I **do** assume you will google definitions while you are working on things.
  - I **do** assume you will include an acknowledgement section in your homework mentioning the people and resources you used in the course of answering problems.
    Example: I worked with Maryam Mirzakhani and Grigori Perelman while completing this assignment. I also used wikipedia to understand Galois cohomology and stack overflow to get me started on an algorithm for enumerating Hamiltonian cycles in a graph.
  - I **do not** assume you will copy each other's work or copy from the internet.

- **Project:** The main component of this course is a project applying the tools you have learned in the class. More specifics will be given in the first few classes, but the general plan is as follows:

  1. The project can range from the applied (e.g. analyze a particular data set) to the theoretical (e.g. extend a particular theorem), and from the known (e.g. review a published result) to the completely original. I will provide some examples/ideas/data sets for projects but, again, you have almost limitless freedom.

  2. Evaluation will be based on an in class presentation during the last week of classes and/or finals week, as well as a writeup.

  3. A project proposal should be presented by mid-semester (specific date to be determined). The proposal is to be at most one page long, describe what your project is going to be, what you need to do in order to complete it, and how it fits with what has been done in applied topology (i.e. does it extend a known theorem, is it another take on a known analysis, etc).

- **Points:** Your grade will be based on the total number of accumulated points from the semester. The *estimated* number of points is below.

Estimated Points	
Homeworks	5 homeworks $\times$ 20 points = 100
Project	100
TOTAL:	200

Course activities:

- The default assumption is that class will be held in-person unless you are told otherwise. I am vaccinated and will be wearing a mask to teach. I try to have small breaks in the lectures for students to try out examples and talk to each other, which will be easiest to do in an in-person setting so I encourage all to join in-person if they are able. I cannot promise that recordings or hybrid teaching will be possible.

- Face coverings must be worn by everyone indoors (including all faculty, staff, students, vendors and visitors) while you are on property owned or governed by MSU or while participating in MSU-related or MSU-sponsored activities. If you have a medical condition that may prevent you from safely wearing a face covering, you should contact MSU's Resource Center for Persons with Disabilities to begin the accommodation process. From the APUE (8/20), individuals "must receive documents attesting to their exemption from the mask mandate before entering an MSU building without a mask." I highly encourage all students to wear masks and get vaccinated in order to protect our community and allow for in-person instruction to continue.

- If you refuse to wear a mask even after being asked, you will be asked to leave the classroom for disruptive behavior. Non-compliance with the mask requirement [causing] disruption in the classroom will result in the initiation of disciplinary action, which could lead to removal from the university.

- The best way to prevent illness is to avoid being exposed to the virus. If you believe you have been exposed to someone with COVID-19, you should self-quarantine and monitor your symptoms. If feeling ill, students should contact MSU's COVID-19 hotline at 855-958-2678 or contact their health care provider. MSU will test any faculty, staff, or student who becomes symptomatic after returning to campus. You may also get tested through the State of Michigan Coronavirus Testing Hotline. Call (888) 535-6136 from 8 a.m. to 5 p.m., Monday through Friday, and press 1 to be connected to an operator who can help you find a nearby location and schedule an appointment. Or, visit Michigan.gov/CoronavirusTest to find locations near you. There are many locations where you can get tested at no cost.

  Anyone diagnosed with COVID-19 should isolate from others for at least 10 days after symptoms first appear and for 24 hours after fever has subsided without the use of fever-reducing medications and other related symptoms are improving. If you tested positive for COVID-19 but showed no symptoms, you should isolate for 10 days after your positive COVID-19 test.

  The bottom line: **If you have tested positive for COVID, if you believe you have been exposed, or if you are experiencing COVID symptoms, do not come to class.**

- There will very likely be times when we can not meet in person. This could be due to university mandated shutdowns. This could be due to exposure of myself or someone else in the class to Covid-19. This could be due to my two young kids' school shutting down due to the same reasoning. In these cases, I ask for your flexibility and graciousness as we navigate this new world together.

  I will post an announcement to Slack about the change in location as soon as I know that it needs to change. D2L is harder to access in general, but I will try to post any announcements there as well. Whenever possible, I will be sure to post the change in location by noon before class. In the case that we need to meet online, we will use the same zoom link as office hours, posted at the top of this syllabus.

Required materials:
While most of the course will be in-person, to be prepared for online days, you will need to ensure that you have the following:

- A computer with a reliable internet connection and functional webcam, microphone, and speakers.

- The ability to run the Zoom video conferencing software, which you can download here: https://msu.zoom.us/support/download

- While not required, use of a webcam is strongly encouraged. Please note that this course has a policy that to the maximal extent possible, in the event that any pets or children wish to make a showing on screen, we will take a brief break to all say hello.

I will also be posting skeleton slides to D2L prior to class. Again, the intention is to post this before noon the day of class. You will likely want to have access either to a printer, or a tablet with annotation ability, in order to follow along in class. I will not be providing print-outs of the slide decks.

Tentative Schedule:
Note that this schedule is only provided as a guide and is very likely subject to change. Please check D2L regularly for reading assignments and true schedule. I will also maintain the schedule as it changes at this link.

Week	Date		Topic	Reading	Other
1	W	9/1	Overview of course, Basic topology definitions	1.1, 1.2, 1.3	
	F	9/3	Morse theory	1.4, 1.5	
2	M	9/6	No class - Labor day		
	W	9/8	Graph theory basics	[outside source?]	
	F	9/10	Simplicial complex;	2.1	
3	M	9/13	Nerve cech & Rips complex	2.2	
	W	9/15	Sparse complexes	2.3	
	F	9/17	Homology pt 1	2.4	HW #1 Due
4	M	9/20	Homology pt 2	2.5	
	W	9/22	Homology: Induced maps	2.5.1	
	F	9/24	Python and homology	[Jupyter]	
5	M	9/27	Filtrations & persistence	3.1	
	W	9/29	Persistence diagram	3.2	
	F	10/1	Persistence algorithm	3.3	HW #2 Due
6	M	10/4	Rips/Cech Complex filtrations	6.1	
	W	10/6	Bottleneck and Wasserstein distance; stability	3.2.?	
	F	10/8	Python and persistence	[Jupyter]	
7	M	10/11	Persistence for PL functions	3.5	
	W	10/13	Optimal generators / basis	5.1	
	F	10/15	Data sparsification	6.2	HW #3 Due
8	M	10/18	Reeb graphs	7.1	
	W	10/20	Merge trees & matrices	My paper?	
	F	10/22	Python (?) Reeb graphs	[Jupyter]	
9	M	10/25	No class - Fall Break		
	W	10/27	Relative Homology	2.5.2	
	F	10/29	Extended persistence	??? 7.2.3?	HW #4 Due
10	M	11/1	Interleaving distance	7.3.1	
	W	11/3	Functional distortion distance	7.3.2	
	F	11/5	Covers & nerves	9.1	
11	M	11/8	What?	9.2	
	W	11/10	Mapper	9.3	
	F	11/12	Python - Mapper	[Jupyter]	HW #5 Due
12	M	11/15	Overflow, student request for topic		
	W	11/17	Persistence images/landscapes	13.1	
	F	11/19	Python - ML and persistence	[Jupyter]	
13	M	11/22	Multiparameter persistence	11.1 +	
	W	11/24	Rivet	[Coding]	
	F	11/26	No class - Thanksgiving Break		
14	M	11/29	Presentations		
	W	12/1	Presentations		
	F	12/3	Presentations		
15	M	12/6	Presentations		
	W	12/8	Presentations		
	F	12/10	Presentations		
			No final exam		

Inclusive classroom behavior:
Respectful and responsible behavior is expected at all times, which includes not interrupting other students, refraining from non-course-related use of electronic devices or additional software during class sessions, and not using offensive or demeaning language in our discussions. Flagrant or repeated violations of this expectation may result in ejection from the classroom, grade-related penalties, and/or involvement of the university Ombudsperson. In particular, behaviors that could be considered discriminatory or harassing, or unwanted sexual attention, will not be tolerated and will be immediately reported to the appropriate MSU office (which may include the MSU Police Department).
In addition, MSU welcomes a full spectrum of experiences, viewpoints, and intellectual approaches because they enrich the conversation, even as they challenge us to think differently and grow. However, we believe that expressions and actions that demean individuals or groups comprise the environment for intellectual growth and undermine the social fabric on which the community is based. These demeaning behaviors are not welcome in this classroom.

Accommodations for Students with Disabilities:
(from the Resource Center for Persons with Disabilities (RCPD): Michigan State University is committed to providing equal opportunity for participation in all programs, services and activities. Requests for accommodations by persons with disabilities may be made by contacting the Resource Center for Persons with Disabilities at 517-884-RCPD or on the web at http://rcpd.msu.edu. Once your eligibility for an accommodation has been determined, you will be issued a Verified Individual Services Accommodation ("VISA") form. Please present this form to the instructor at the start of the term and/or two weeks prior to the accommodation date (test, project, etc.). Requests received after this date may not be honored.

Academic honesty:
Intellectual integrity is the foundation of the scientific enterprise. In all instances, you must do your own work and give proper credit to all sources that you use in your papers and oral presentations – any instance of submitting another person's work, ideas, or wording as your own counts as plagiarism. This includes failing to cite any direct quotations in your essays, research paper, class debate, or written presentation. The MSU College of Engineering adheres to the policies of academic honesty as specified in the General Student Regulations 1.0, Protection of Scholarship and Grades, and in the all-University statement on Integrity of Scholarship and Grades, which are included in Spartan Life: Student Handbook and Resource Guide. Students who plagiarize will receive a 0.0 in the course. In addition, University policy requires that any cheating offense, regardless of the magnitude of the infraction or punishment decided upon by the professor, be reported immediately to the dean of the student's college. (See also the Academic Integrity webpage.)
It is important to note that plagiarism in the context of this course includes, but is not limited to, directly copying another student's solutions to assignments; copying materials from online sources, textbooks, or other reference materials without citing those references in your source code or documentation, or having somebody else do your in-class work or homework on your behalf. Any work that is done in collaboration with other students should state this explicitly, and have their names as well as yours listed clearly.
More broadly, we ask that students adhere to the Spartan Code of Honor academic pledge, as written by the Associated Students of Michigan State University (ASMSU):
"As a Spartan, I will strive to uphold values of the highest ethical standard. I will practice honesty in my work, foster honesty in my peers, and take pride in knowing that honor is worth more than grades. I will carry these values beyond my time as a student at Michigan State University, continuing the endeavor to build personal integrity in all that I do."

Limits to confidentiality:
Essays, journals, and other materials submitted for this class are generally considered confidential pursuant to the University's student record policies. However, students should be aware that University employees, including instructors, may not be able to maintain confidentiality when it conflicts with their responsibility to report certain issues to protect the health and safety of MSU community members and others. As the instructor, I must report the following information to other University offices (including the Department of Police and Public Safety) if you share it with me:

- suspected child abuse/neglect, even if this maltreatment happened when you were a child,

- allegations of sexual assault or sexual harassment when they involve MSU students, faculty, or staff,

and

- credible threats of harm to oneself or to others.

These reports may trigger contact from a campus official who will want to talk with you about the incident that you have shared. In almost all cases, it will be your decision whether you wish to speak with that individual. If you would like to talk about these events in a more confidential setting you are encouraged to make an appointment with the MSU Counseling Center.

Drops and Adds:
The last day to add this course is September 8, 2021 at 8:00pm. The last day to drop this course with a 100 percent refund and no grade reported is September 27, 2021, at 8:00pm. See the registrar's page for up-to-date information regarding dates. You should immediately make a copy of your amended schedule to verify you have added or dropped this course.

Changes to Syllabus:
The syllabus may also be adjusted if needed. These types of changes will be announced during class, by email and/or in the course's slack channel.

Disruptive Behavior:
Article 2.III.B.4 of the Student Rights and Responsibilities (SRR) for students at Michigan State University states: "The student's behavior in the classroom shall be conducive to the teaching and learning process for all concerned." Article 2.III.B.10 of the SRR states that "The student and the faculty share the responsibility for maintaining professional relationships based on mutual trust and civility." General Student Regulation 5.02 states: "No student shall . . . interfere with the functions and services of the University (for example, but not limited to, classes . . .) such that the function or service is obstructed or disrupted. Students whose conduct adversely affects the learning environment in this classroom may be subject to disciplinary action through the Student Judicial Affairs office.

Grief Absence Policy:
Michigan State University is committed to ensuring that the bereavement process of a student who loses a family member during a semester does not put the student at an academic disadvantage in their classes. If you require a grief absence, you should complete the "Grief Absence Request" web form no later than one week after knowledge of the circumstance. I will work with you to make appropriate accommodations so that you are not penalized due to a verified grief absence.