Course Change Request

New Course Proposal

Date Submitted: 10/14/24 1:45 pm

Viewing: MATH 735 : Computational and Applied Topology

Last edit: 10/29/24 12:19 pm

Changes proposed by: esander

In Workflow

1. **MATH Chair**
2. **SC Curriculum Committee**
3. SC Assistant Dean
4. Assoc Provost-Graduate
5. Registrar-Courses
6. Banner

Approval Path

1. 10/24/24 3:07 pm Maria Emelianenko (memelian): Approved for MATH Chair

Are you completing this form on someone else's behalf?

No

Effective Term: Fall 2025

Subject Code: MATH - Mathematics

Course Number: 735

Bundled Courses:

Is this course replacing another course? No

Equivalent Courses:

Catalog Title: Computational and Applied Topology

Banner Title: Computational & App. Topology

Will section titles vary by semester? No

Credits: 3

Schedule Type: Lecture

Hours of Lecture or Seminar per week: 3

Repeatable:

May be only taken once for credit, limited to 3 attempts (N3)

Max Allowable Credits: 3

Default Grade Mode: Graduate Regular

Recommended Prerequisite(s):

Math 631

Recommended Corequisite(s):

Required Prerequisite(s) / Corequisite(s) (Updates only):

Registrar's Office Use Only - Required Prerequisite(s)/Corequisite(s):

And/Or	(	Course/Test Code	Min Grade/Score	Academic Level	)	Concurrency?

Registration Restrictions (Updates only):

Registrar's Office Use Only - Registration Restrictions:

Field(s) of Study:

Class(es):

Level(s):

Degree(s):

School(s):

Catalog Description:

This course gives a basic introduction to computational and applied aspects of topology. It is a combination of topics from geometry, topology, and algorithms and concentrates on topics such as graphs, surfaces, triangulations, complexes, homology, cohomology, duality, Morse theory, persistent homology, spectral sequences, and stability. It is also demonstrated how some of these methods can be used in applied situations and in the study of dynamics.

Justification:

Topological data analysis is one of the fast growing fields at the moment, and courses like this are taught at many universities. For students interested in data sciences, this course is essential.

Does this course cover material which crosses into another department? No

Learning Outcomes:

Learning objectives: Students will learn computational aspects of topology. This includes:

- Learning to compute topology of graphs, surfaces, triangulations, and complexes.
- Learning to work with homology and Morse theory in a computational setting.
- Learning to use persistent homology, and stability, including applications.
- Time permitting, learning to use cohomology, duality, and spectral sequences.

Will this course be scheduled as a cross-level cross listed section? No

Attach Syllabus

Math735Syllabus.pdf

Additional Attachments

Staffing:

Thomas Wanner, Ben Schweinhart

Relationship to Existing Programs:

This will strengthen the offerings for the Math PhD students. It allows students to become familiar with a very important interdisciplinary field that has applications throughout science.

Relationship to Existing Courses:

The department has a number of computational courses and a number of topological courses, but this course would be the first that lies in the intersection of these two fields.

Additional Comments:

Reviewer Comments

Key: 18786

Computational Topology

Math 735

General Information:

Prerequisites:	A thorough knowledge of advanced calculus and linear algebra is assumed. Also, familiarity with the "Theorem-Proof" style of presentation is important, and basic knowledge of groups is helpful.
Textbook:	H. Edelsbrunner, J. Harer, *Computational Topology*, American Mathematical Society, Providence, RI, 2010.

Important Links:

- Detailed syllabus (including recommended additional books)
- Relevant official GMU policies
- Brief course advertisement

Syllabus:

This course gives a basic introduction to computational aspects of topology. It is a combination of topics from geometry, topology, and algorithms and concentrates on topics such as graphs, surfaces, triangulations, complexes, homology, cohomology, duality, Morse theory, persistent homology, spectral sequences, and stability. Time permitting, we also demonstrate how some of these methods can be used in applied situations and in the study of dynamics. A more detailed syllabus can be found here. It will be updated weekly.

Homework Assignments:

Homework problems will be assigned once a week and posted on Blackboard/Canvas in the Assignments section. Some of these assignments will be graded and count towards your homework score. While the remaining ones do not have to be handed in, I do advise everyone strongly to study them and write out the solutions properly. I will go through many of the homework problems in the following class and you will not benefit from this if you have not made a serious attempt at solving them.

Grading Policy:

Your final grade in the course will be determined from your performance in the homework assignments, a final project/presentation, and your attendance and class participation. Weights for these items will be distributed approximately according to the following schedule:

Homework	Final Project/Presentation	Attendance
60%	30%	10%

Relevant George Mason
Official University Policies

The following policies apply to all courses at George Mason University:

1. Attendance and class participation is a portion of your grade. You will be graded on attending and actively participating in class discussions.
2. In general, late assignments are not accepted except in exceptional circumstances. Likewise, makeup for missed exams is only with clear documentation of a valid reason for missing the exam.
3. Feel free to send an email with your preferred name and gender pronoun. Note that Mason provides online methods for students to change their name and pronouns on Mason records.
4. This classroom fosters inclusivity in keeping with George Mason's core values.
5. Being that this is a computational class, computers are required to complete many of the assignments. That being said, you will not need to bring a computer to class.
6. The Common Policies Addendum (via online link, PDF or document text), with policies about Academic Standards, Accommodations for Students with Disabilities, FERPA, and Title IX.
7. You are responsible for the accuracy of your own schedule. Check Patriot Web regularly to verify that you are registered for the classes that you think you are. A student who is not registered may not continue to attend class. Faculty are not permitted to grade work of students who do not appear on the official class roster.
8. You are responsible for knowing the last days to drop and add this class.
9. Once the add and drop deadlines have passed, instructors do not have the authority to approve any requests from students to add or drop/withdraw late. It is NOT permissible to drop the class and leave it at that. It needs approval. Late adds (up until the last day of classes) must be reviewed and approved by the department chair of the course being offered. They will be approved only in the case of a documented university error (such as a problem with Financial Aid being processed). All student requests for withdrawals and retroactive adds (after the last day of classes) must be reviewed by the student's academic dean. In the case of students whose major is in COS, this is the office of Undergraduate Academic Affairs in Enterprise.
10. Instructors are required to give the final exam at the time and place published in the Schedule of Classes, as set by the Registrar. It cannot change be changed. You need to plan vacation (make plane reservations, etc.) around these published dates.
11. Once final grades have been recorded, instructors cannot accept any work to change that course grade. Grade changes can only be approved when they are due to a calculation or recording error on the part of the instructor.
12. An IN (incomplete) grade is a very special grade that can only be applied for in writing. It can only be given in cases in which a student is passing a course and has a very limited amount of work left to complete the course.
13. Federal law (a law known as FERPA) requires the protection of privacy of student information. Therefore, no instructor on campus can speak about a student's record with anyone other than the student. The record includes how a student is doing in a course, whether a student has attended class, information about grades, whether a paper has been turned in. Anything. This prohibition includes parents, siblings, and spouses, anyone.

Computational Topology

Math 735

The following table contains the detailed schedule for the course. This page will be updated regularly throughout the semester.

Week	Class	Date	
1	1	01/22	**I. Graphs**
			1. Connected Components
			2. Curves in the Plane
2	2	01/29	3. Knots and Links
			4. Planar Graphs
3	3	02/05	**II. Surfaces**
			1. Two-Dimensional Manifolds
4	4	02/12	2. Searching a Triangulation
			3. Self-Intersections
			4. Surface Simplification
5	5	02/19	**Student Presentations:**
			Ahsan Chowdhury [1, 2]
			Patrick O'Neil [3]
			Diego Torrejon [4, 5]
			Byong Kwon [6]
6	6	02/26	**III. Complexes**
			1. Simplicial Complexes
7		03/05	**No class! (Snow Day)**
8		03/12	**No class! (Spring Break)**
9	7	03/19	2. Convex Set Systems
			3. Delaunay Complexes
			4. Alpha Complexes
			IV. Homology
10	8	03/26	1. Homology Groups
11	9	04/02	2. Matrix Reduction
12	10	04/09	3. Relative Homology
13	11	04/16	4. Exact Sequences
14	12	04/23	**Student Presentations:**
			Marilyn Vazquez [7]
			Mahendra Panagoda [8]
			James Cameron [9, 10]
15	13	04/30	**V. Persistence**
			1. Persistent Homology
			2. Computing Persistence
16	14	05/06	3. Extended Persistence
			4. Stability Theorems
	15	05/07	**VI. Applications**
			1. Applications to Dynamical Systems
			2. Conley Index and Connecting Orbits

In addition to the textbook, the following books might be useful as secondary reading:

- T. Kaczynski, K. Mischaikow, and M. Mrozek, *Computational Homology*, Springer, 2004.
- J.R. Munkres, *Elements of Algebraic Topology*, Addison-Wesley, 1984.
- M. Robinson, *Topological Signal Processing*, Springer, 2014.

The following papers will be presented by students on February 19 and April 23:

1. M. Gameiro, K. Mischaikow, W. Kalies, *Topological characterization of spatial-temporal chaos*, Physical Review E, 70(3):035203, 2004.
2. K. Krishan, M. Gameiro, K. Mischaikow, M. Schatz, H. Kurtuldu, S. Madruga, *Homology and symmetry breaking in Rayleigh-Benard convection: Experiments and simulations*, Physics of Fluids, 19:117105, 2007.
3. H. Edelsbrunner, E.P. Mücke, *Simulation of simplicity: A technique to cope with degenerate cases in geometric algorithms*, ACM Transactions on Graphics, 9(1):66-104, 1990.
4. M. Gameiro, K. Mischaikow, T. Wanner, *Evolution of pattern complexity in the Cahn-Hilliard theory of phase separation*, Acta Materialia, 53(3):693-704, 2005.
5. T. Wanner, E.R. Fuller Jr., D.M. Saylor, *Homological characterization of microstructure response fields in polycrystals*, Acta Materialia, 58(1):102-110, 2010.
6. K. Murasugi, *Knot Theory & its Applications*, Birkhäuser, 2008. (Sections 1.1-1.3 and 4.1.)
7. J. Perea, G. Carlsson, *A Klein-bottle-based dictionary for texture representation*, International Journal of Computer Vision, 107:75-97, 2014.
8. C. Topaz, L. Ziegelmeier, T. Halverson, *Topological data analysis of biological aggregation models*, Preprint, 2014.
9. V. de Silva, R. Ghrist, *Homological sensor networks*, Notices of the AMS, 54(1):10-17, 2007.
10. Y. Baryshnikov, R. Ghrist, *Target enumeration via Euler characteristic integrals*, SIAM Journal on Applied Mathematics, 70(3):825-844, 2009.
