MATH 392 – Seminar: Applied Computational Topology

Spring 2016
MWF Noon to 12:50 PM, Swords 321

Syllabus (1/26/16)

Instructor: Prof. David Damiano, 341 Swords, 793-2476/3374
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Office Hours: MT 11 AM to Noon, WR 1:00 - 2:00 PM, and by appointment.

Course Home Page: `http://math.holycross.edu/~dbd/math392/math392.html`

Course Materials: (Required) *Computational Topology: An Introduction*, Herbert Edelsbrunner and John L. Harer. Publisher: American Mathematical Society, 2010. (Available on-line through Amazon.com. Used copies will be fine.)

Prerequisites: MATH 242 and MATH 244 or permission of the instructor. (MATH 244 may be taken simultaneously.)

Intended Audience: This course is designed for upper division mathematics majors with a knowledge of mathematics through the department's intermediate level courses and an interest in applications of mathematics. This course fulfills the department's Applied breadth area requirement. as well as it's project course requirement. *No prior knowledge of topology or computing or the applications will be assumed.*

Applied Computational Topology–What is it? Let's take the three words in reverse order.

Topology is the study of the properties of shapes of objects that do not change under continuous deformations. For example, a basketball and a soccer ball are different sizes but are both spheres. Both have insides and outsides separated by the material of the ball. Similarly, a deflated basketball has this characteristic: it has an inside and outside and there is no way to go from the inside to the outside without passing through the surface of the ball. We might say that in either case the ball encloses a "void." The existence of voids in an object or a set is an example of a property of shape that does not change under continuous deformations. We will call this a topological property. Topological properties are often expressed algebraically using the language of groups. For instance, the presence of a void will be represented by a non-trivial (so not equal to the identity) element of a particular group associated to the object.

Computational refers to algorithms that are used to compute the elements of these groups. It isn't evident at first how we might do this. It begins by representing objects in a form that are amenable to calculation and developing methods that work with these forms to produce group elements. These methods can be applied to abstract shapes that do not necessarily represent physical objects.

Applied refers to the sets or object that we might apply the algorithms to in order to produce groups. For example, the object might be a compounds soap bubble. We would represent it in the form suitable for computation and calculate the group elements representing the voids in the bubble. After some thought, this should at least make intuitive sense. On the other hand, we will also be interested in data sets, that is, collections or clouds of points in a possibly high dimensional Euclidean space. The intuition is that the cloud is a sample of points filling out an unspecified region of this high dimensional space. The questions for us are whether the region has topological features that might be of interest for the application.

Topics: We will spend time on each of the three threads. The topological topics will come mainly from Chapters III through VII of the text. We will fill in the necessary mathematical background as we go. The text also discusses algorithms in places. We will go over some of these, though not in as much detail as the topology. Because we have high level software available to do our calculations, it will be more important for us to spend time using the software. We will consider motivating applications as we go. These will mostly come from research papers since the subject is relative new.

Class Format: Two thirds or so of the classes will be lectures. The remaining classes will be devoted to student presentations, computer labs, and guest lectures.

Assignments, hour exam and final project: There will be regular assignments including traditional mathematical homework, short oral presentations on aspects of topology, algorithms, or applications, and a final project.

There will be a 90 minute midterm (held at night) that focuses on mathematical aspects of the course. This will be in March the first or second week after spring break. (day and time to be arranged).

In lieu of a final exam there will be a final project. These will be two or three-person team projects concerning an application of interest to you. The topics may be chosen from topics suggested by the course or from your reading. The project will have several components: (i) identification of a topic (ii) a search of the literature (iii) identification of a data set (iv) a topological analysis of the data using software (v) a write-up of the literature search, the techniques, and the analysis and (vi) an oral presentation of roughly 40 minutes in length. The last four days of the semester will be devoted to the oral presentations. The written reports will be due on the last day of reading period.

Grading: There are several components to the course grade.

Homework	30%
Group work/Computer Labs	15%
Short Oral Presentations	5%
Mid-term Exam	20%
Final Project	30%
Total	100%

Academic Honesty: The Department of Mathematics and Computer Science adheres to the College's policy on Academic Honesty, which may be found on-line in the College Catalogue. In addition, the department has formulated the attached statement intended to amplify the policy as to how it might apply in mathematics and computer science.

Name:

Math classes you have taken or are taking:

CS classes you have taken or are taking:

Do you have experience with MATLAB? in what context?

Science classes you have taken or are taking:

Science interests (not necessarily from a class):