Course Title	**Special Topics: Topological Data Analysis and Graph Signa Processing**
Course number	**DS-GA-3001**
Time	**Section 1: <Weekdays> 5:30PM – 7:10PM**
	Lab 1: <Weekdays> 7:20PM – 8:10PMAM
Room	**SILV_405 (ACREGI)**
Credits	**3**

Teaching Team

Instructor: Professor Luis Gustavo Nonato
Professor Harish Doraiswamy

(*Discipline Core*) (3 credits) – Introduction to fundamental concepts of computational topology and graph signal processing tools currently used in data science with focus on urban data. The content includes a solid mathematical description of the basic theory as well as a detailed discussion of computational aspects involved in practical implementation. Examples and applications involving large datasets are an integral part of the course.

Learning objectives

A lot of data commonly available from multiple domains involve either a spatial component (Eg. Biology, climate sciences, astronomy, etc.) or some sort of connectivity information amongst themselves which can be represented as graphs (Eg. Urban data, social media data etc.). The goal of this course is to introduce basic mathematical concepts and the computational tools derived from them to help in the analyses of such data. Through this course, the student will learn fundamental concepts, tools, and techniques from computational topology and graph signal processing applied to such data sets. Examples involving real world data sets will aid students in the application of these analyses techniques in practical scenarios.

The course is essentially divided into two major parts, each of which will have written and / or programming assignments. The first major part will present the theory and computational aspects of **computational topology.** The second part concerns the fundamental concepts involved in **graph signal processing**. Throughout the course, we will improve students programming skills, using Python as primary language, although other languages might be introduced as needed.

Major references

We will not follow any text book, but the ones below might be useful in some parts of the course

- Chung, Fan RK. Spectral graph theory. Vol. 92. American Mathematical Soc., 1997.
- Brouwer, Andries E., and Willem H. Haemers. Spectra of graphs, Springer Science & Business Media, 2011.
- Computational Topology: An Introduction. Edelsbrunner and Harer.
Topology for Computing. Afra Zomorodian.

Class Mechanics

Each student will be **required** to attend one lecture and one lab session each week as assigned. Our goal will be to post material covered in class (including slides and reading materials), by the day before the lectures and/or lab.

Lectures will be approximately 90 minute long.

Labs will typically have a shorter 10-30 minute presentation followed by hands work by the students. Students are advised to take a computer to class.

Assignments

There will be four assignments, a midterm and a final presentation. The due date of each assignment will be announced during classes at least fifteen days before the deadline.

Assignments will not be accepted late. Students will be given a one-time two-day exemption for an unexpected event.

Plagiarism will be dealt with very strictly.

Grading

Your grade will be based on the following combination:

Midterm: 25%
Final: 25%
Assignments: 50% (expect 4 assignments)

Tentative Schedule - Spring 2017

(All lectures by Harish or Gustavo unless specified)

Lecture 1 (01/25): Introduction to Topology: Definitions, data representations.
Lab: Using existing tools for visualizing spatial data.

Lecture 2 (02/01): Level set analyses. Definitions and algorithms.
Lab: Computing and visualizing level sets of different scalar functions.

Lecture 3 (02/08): Introduction to Morse theory
Lab: Computing critical points of scalar functions.

Lecture 4 (02/15): Level set topology: Contour trees and Reeb graphs
Lab: TBD

Lecture 5 (02/22): Topological Persistence
Lab: TBD

Lecture 6 (03/01): Gradient fields.
Lab: TBD

Lecture 7 (03/08): Midterm Student Presentations
Lab: No lab assigned

Lecture 8 (03/22): Review of Eigen-Decomposition of Matrices
Lab: Computing the spectrum of a symmetric matrix with Scipy

Lecture 9 (03/29): Introduction to Spectral Graph Theory
Lab: Building a Laplacian Matrix from a KNN graph; Spectrum of a graph into practice

Lecture 10 (04/05): Graph Fourier Transform I
Lab: Computing the Graph Fourier Transform: Band-pass filtering

Lecture 11 (04/12): Graph Fourier Transform II: Approximating the spectrum
Lab: Dealing with time-varying data

Lecture 12 (04/19): Review of Wavelets
Lab: No lab assigned

Lecture 13 (04/26): Wavelets on graphs via spectral graph theory
Lab: Wavelet coefficients as feature vectors

Lecture 14 (05/03): Final Student Presentation

Lab: No lab