GEOG 470/770 – CMSC 498Q
Algorithms for Geospatial Computing

Instructor: Leila De Floriani
E-mail*:* deflo@umd.edu
Office hours: 2:00pm-3:00pm Tuesday (1135 LeFrak Hall), or online, or by appointment.

Schedule of Classes: Tuesday and Thursday: 12:30pm – 1:45pm, 1201 LeFrak Hall

Course Description

Geospatial data science deals with representation, and analysis of data in which the spatial component plays a key role. The aim of the course is to familiarize the student with the fundamental algorithms in geospatial data science and their implementation in geographical information systems and in geospatial data analysis software tools. The course provides an introduction to fundamental geospatial objects and models, and to geometric algorithms, which are the basic building blocks for spatio-temporal data processing and analysis. It focuses on algorithms and data structures for managing point clouds, which are at the basis for geospatial data exploration and analysis, and discusses their application to processing and analysis of LiDAR (Light Detection And Ranging) data in the context of terrain reconstruction, urban modeling, forest management and coastal data management and analysis. Emphasis is placed on surface and scalar field modeling, such as terrains, discussing both raster and vector models as well as algorithms for building, querying and performing morphological and visibility computations on them. Algorithms for road network analysis and reconstruction are also studied in connection with real-world applications.

Prerequisites. GEOG 276 or equivalent or minimum grade of C- in CMSC330 and CMSC351 or permission of the instructor.

Course Learning Objectives

Upon successful completion of the course the students will be able to:

- Acquire in-depth knowledge of fundamentals of algorithms for geospatial data science.
- Learn techniques for efficiently encoding, manipulating and querying geospatial data.
- Gain substantial understanding of how geospatial data are actually processed in modern geographical information systems.
- Learn how to design, use and implement algorithms dealing with geospatial data, with emphasis on point data processing and analysis, on terrain modeling and on road network analysis.
- Apply algorithms for discrete and continuous geospatial data to LiDAR data processing and analysis, and algorithms for road network routing and reconstruction to real-world data sets.

Required Resources and Corse Communication

The main course communication is carried out through *Canvas* within the University of Maryland *Enterprise Learning Management System* (ELMS; https://elms.umd.edu). All students enrolled in the course have access to the system. *Canvas* is be used by the instructor to post course slides and notes, lecture recordings, assignments and grades, and by the students to submit their assignments and questions.

Course material consists of *course notes* in the form of slides posted on *Canvas*. This is a list of recommended books:

- N. Xiao, *GIS Algorithms*, 2016, SAGE Publications.
- M.J. de Smith, M.F. Goodchild, P.A. Longley, *Geospatial Analysis: A Comprehensive Guide to Principles, Techniques and Software Tools* (sixth edition), 2018.
- M. F. Worboys, M. Duckham, *GIS: A Computing Perspective*, 2004, CRC Press.
- M. Goodrich, R. Tamassia, M.H. Goldwasser, *Data Structures and Algorithms in Python*, 2013, Wiley and Sons.

Course Structure

The course consists of a series of lectures, homework assignments and a project. The topics covered in class are:

- ***Fundamental geospatial objects data models****:* points, lines, regions, maps, fields (terrains), networks.
- ***Basic geometric algorithms:*** point-in-polygon, convex hull, line segment intersections, polygon overlay, polygon triangulation.
- ***Map modeling and processing:*** raster and vector models, entities and connectivity relations in a vector model, data structures for maps; connectivity and spatial queries, map overlay.
- ***Representing, processing and analyzing point data****:*
    - uniform grids, hierarchical spatial indexes (quadtrees, kd-trees, R-trees), Voronoi diagrams;
    - algorithms for point location, nearest neighbor, and range searching;
    - clustering point clouds: hierarchical nearest neighbor, k-means, density-based clustering.
- ***Surface and field modeling and analysis:***
    - Triangulated Irregular Networks (TINs): data structures, Delaunay triangulation (definitions and properties), Delaunay triangulation algorithms;
    - raster models: regular grids, gridding and deterministic interpolation algorithms;
    - computing terrain morphology: slope, aspect, curvature, critical points and watershed segmentation on grids and TINs;
    - computing visibility on terrains*:* algorithms for viewshed analysis and horizon computation.
- ***Examples of applications***:
    - terrain reconstruction from LiDAR point clouds;
    - rooftop reconstruction from LiDAR point clouds in urban environments;
    - bathymetry and coastline reconstruction for coastal data processing and analysis;
    - tree mapping and reconstruction from LiDAR data in forest management for carbon emission or visualization.
- ***Road network computation and reconstruction*****:**
    - networks: definitions, basic data structures, hierarchical networks;
    - algorithms for route computations in road networks;
    - road network reconstruction from GPS and satellite data.

Major Assignments

Homework Assignments. There are two kinds of homework assignment, a reading assignment and a programming assignment. *Reading assignment*s consist of answering questions about material in recommended readings or presented in class, and designing algorithms for solving specific problems. The

purpose is to help the student to elaborate on the various notions and algorithms discussed in class, also in preparation for the midterm and final exams. *Programming assignments* consist of studying and implementing algorithms discussed in class, in Python, or C++.

Project. The project consists of designing and implementing algorithms for processing and analyzing geospatial data in the context of some specific application problem discussed in class. Examples are: developing a tool for segmenting LiDAR point clouds, or raster images in an urban environment, reconstructing trees in a city or in a forest from sets of LiDAR points, computing morphological information from bathymetric data for precision navigation or ocean coastal modeling, reconstructing a road network from satellite data, etc. The project is to be developed in Python, or C++. The project for graduate students will be defined by an individual consultation with the instructor.

Midterm and final exams. The course includes two non-cumulative exams: one mid-term exam, and one final exam. Although the exams are not cumulative, understanding of the notions and principles acquired in earlier parts of the course will be necessary to answer exam questions in the later parts. All exams will present a combination of questions requiring the definitions of specific representations or the description of some techniques all seen in class and described in the course notes. In the in-persom version of the class, both exams will be closed books and close notes. In the online version, both exams will be structured to be performed open book and open notes.

Research paper (only for graduate students). Graduate students are also required to prepare a research paper with a review of the literature in the specific topic, and present it in class.

Grading Structure and Policies

- ***Mid-term*** exam – 20%
- ***Homework*** – 25%
- ***Project*** - 30% *(Research project and paper for graduate students)*
- ***Final*** exam – 25%

Final letter grades are assigned based on the percentage of total assessment points earned, as specified in the table below. Any formal grade disputes must be submitted in writing and within one week of receiving the grade.

Final Grade Cutoffs									
+	97.00%	+	87.00%	+	77.00%	+	67.00%	+	
A	94.00%	B	84.00%	C	74.00%	D	64.00%	F	<60.0%
-	90.00%	-	80.00%	-	70.00%	-	60.00%	-	

Course Guidelines

Class attendance. Requirements for this course include attendance and participation in the lectures, completion of programming assignments and/ or a research paper, a midterm exam, and a final exam. Course readings will come from a comprehensive set of slides posted by the instructor, which will form the course notes. Lectures will also include information not present in the posted notes, or in the recommended books. The exams will be based on all material presented in the lectures and in any required reading.

Communications with the instructor. Please contact the instructor by email at deflo@umd.edu for academic, and intellectual concerns/questions. Important announcements will be sent via ELMS messaging. You must make sure that your email and announcement notifications (including changes in assignments and/or due dates) are enabled in ELMS so you do not miss any messages. You are responsible for checking your email and Canvas/ELMS inbox with regular frequency.

Communications with peers. With a diversity of perspectives and experience, we may find ourselves in disagreement and/or debate with one another. As such, it is important that we agree to conduct ourselves in a professional manner and that we work together to foster and preserve a virtual classroom environment in which we can respectfully discuss and deliberate controversial questions. I will make every reasonable attempt to create an atmosphere in which each student feels comfortable voicing their argument without fear of being personally attacked, mocked, demeaned, or devalued. Any behavior (including harassment, sexual harassment, and racially and/or culturally derogatory language) that threatens this atmosphere will not be tolerated. Please alert me immediately if you feel threatened, dismissed, or silenced at any point during our semester together and/or if your engagement in discussion has been in some way hindered by the learning environment. Disruptive behavior of any kind will not be tolerated. Students who are unable to demonstrate civility with one another, the teaching assistants, or the instructor will be subject to referral to the Office of Student Conduct or to the University Campus Police. Students are expected to adhere to the Code of Student Conduct.

Campus Policies

It is our shared responsibility to know and abide by the University of Maryland's policies that relate to all courses, which include topics like:

- Academic integrity
- Mask mandates
- Student and instructor conduct
- Accessibility and accommodations
- Attendance and excused absences
- Grades and appeals
- Copyright and intellectual property

Please visit **www.ugst.umd.edu/courserelatedpolicies.html** for the Office of Undergraduate Studies' full list of campus-wide policies and follow up with me if you have questions.

Academic Integrity

The University's Code of Academic Integrity is designed to ensure that the principles of academic honesty and integrity are upheld. In accordance with this code, the Smith School does not tolerate academic dishonesty. Please ensure that you fully understand this code and its implications because all acts of academic dishonesty will be dealt with in accordance with the provisions of this code. All students are expected to adhere to this Code. It is your responsibility to read it and know what it says, so you can start your professional life on the right path.

It is important to note that course assistance websites, such as CourseHero, are not permitted sources, unless the instructor explicitly gives permission for you to use one of these sites. Material taken or copied from these sites can be deemed unauthorized material and a violation of academic integrity. These sites offer information that might not be accurate and that shortcut the learning process, particularly the critical thinking steps necessary for college-level assignments.

Additionally, it is understandable that students may use a variety of online or virtual forums for course-wide discussion (e.g., GroupME or WeChat). Collaboration in this way regarding concepts discussed in this course is permissible. However, collaboration on graded assignments is strictly prohibited unless otherwise stated. Examples of prohibited collaboration include: asking classmates for answers on quizzes or exams, asking for access codes to clicker polls, etc. Finally, on each exam or assignment you must write out and sign the following pledge:

"I pledge on my honor that I have not given or received any unauthorized assistance on this exam/assignment."

Please visit the Office of Undergraduate Studies' full list of campus-wide policies and follow up with me if you have questions.

If a student ever feel pressured to comply with someone else's academic integrity violation, please reach out to the instructor straight away. Also, if a student is ever unclear about acceptable levels of collaboration, please ask.

Resources and Accommodations

Accessibility and Disability Services. The University of Maryland is committed to creating and maintaining a welcoming and inclusive educational, working, and living environment for people of all abilities. The University of Maryland is also committed to the principle that no qualified individual with a disability shall, on the basis of disability, be excluded from participation in or be denied the benefits of the services, programs, or activities of the University, or be subjected to discrimination. The **Accessibility & Disability Service (ADS)** provides reasonable accommodations to qualified individuals to provide equal access to services, programs and activities. ADS cannot assist retroactively, so it is generally best to request accommodations several weeks before the semester begins or as soon as a disability becomes known. Any student who needs accommodations should contact me as soon as possible so that I have sufficient time to make arrangements. For assistance in obtaining an accommodation, contact Accessibility and Disability Service at 301-314-7682, or email them at **adsfrontdesk@umd.edu**. Information about **sharing your accommodations with instructors**, **note taking assistance** and more is available from the **Counseling Center**. Every effort will be made to accommodate students who are registered with the Disability Support Service (DSS) Office and who provide the instructor with a University of Maryland DSS Accommodation form. This form must be presented to the instructor at the beginning of classes. The instructor will not be able to accommodate students who are not registered with DSS or who provide the instructor with documentation which has not been reviewed and approved by UM's DSS Office.

Student Resources and Services. Taking personal responsibility for your own learning means acknowledging when your performance does not match your goals and doing something about it. I hope you will come talk to me so that I can help you find the right approach to success in this course, and I encourage you to visit UMD's Student Academic Support Services website to learn more about the wide range of campus resources available to you. In particular, everyone can use some help sharpening their communication skills (and improving their grade) by visiting UMD's Writing Center and schedule an appointment with the campus Writing Center. You should also know there are a wide range of resources to support you with whatever you might need (UMD's Student Resources and Services website may help). If you feel it would be helpful to have someone to talk to, visit UMD's Counseling Center or one of the many other mental health resources on campus.

Basic Needs Security. If you have difficulty affording groceries or accessing sufficient food to eat every day, or lack a safe and stable place to live, please visit UMD's Division of Student Affairs website for information about resources the campus offers you and let me know if I can help in any way.

Technology Policy. Please refrain from using cellphones, laptops, and other electronic devices during class sessions unless we have designated such use as part of a class exercise**.**

Netiquette Policy. Netiquette is the social code of online classes. Students share a responsibility for the course's learning environment. Creating a cohesive online learning community requires learners to support and assist each other. To craft an open and interactive online learning environment, communication has to be conducted in a professional and courteous manner at all times, guided by common sense, collegiality and basic rules of etiquette**.**

Participation. Attendance will be crucial to note-taking and thus your performance in this class. Attendance is particularly important also because class discussion will be a critical component for your learning, and thus it is expected for every session. Students with a legitimate reason to miss a live session should communicate in advance with the instructor, except in the case of an emergency. Students who miss a live session are responsible for learning what they miss from that session. Additionally, students must complete all readings and assignments in a timely manner in order to fully participate in class.

Course Evaluation. Please submit a course evaluation through CourseEvalUM in order to help faculty and administrators improve teaching and learning at Maryland. All information submitted to CourseEvalUM is confidential. Campus will notify you when CourseEvalUM is open for you to complete your evaluations for fall semester courses. Please go directly to the Course Eval UM website to complete your evaluations. By completing all of your evaluations each semester, you will have the privilege of accessing through Testudo, the evaluation reports for the thousands of courses for which 70% or more students submitted their evaluations.