University of Maryland at College Park Department of Geographical Sciences GEOG 498I / 788I: Algorithms for Geospatial Computing (Spring 2019)

Instructor: Professor Leila De Floriani **Office:** LeFrak 1169, and AV Williams 3161 **E-mail***:* deflo@umiacs.umd.edu (preferred) **Office hours:** 10:00-11:00am Tuesday and Thursday (LeFrak1169)

Schedule of Classes: Tuesday and Thursday 11:00am – 12:15pm, LeFrak 1171

Course Description

Geospatial data science deals with representation, and analysis of data in which the spatial components 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 analysis software tools. The course provides an introduction to fundamental geometric primitives and algorithms, which are the basic building blocks for discrete and continuous spatial data processing. We will focus on algorithms and data structures for managing point data, which are at the basis for geospatial data exploration and analysis. Emphasis will also be 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 drainage and visibility computations on them. Applications involving processing and analysis of LiDAR data in the context of terrain reconstruction, urban modeling, forest management and coastal data analysis will be extensively explored. Special attention will be paid to scalable algorithms and representations for big geospatial data. Students with some programming background will highly benefit from this course.

Course Learning Objectives

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

- Have 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 and implement algorithms dealing with geospatial data, with emphasis on point data processing and analysis and on terrain modeling and analysis.
- Apply algorithms for discrete and continuous geospatial data to LiDAR data processing and analysis.

Course Communication

The main course communication will be 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. In addition to communications, *Canvas* will be used by the instructor to post, course slides, and notes, assignments and grades, and by the students to submit their assignments.

Course Material

Course notes in the form of slides posted on *Canvas*.

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.

List of Topics

- *Fundamental geospatial concepts:* objects (points, lines, regions), maps, fields (terrains), networks
- *Geospatial data models*: raster, vector, Triangulated Irregular Networks (TINs),

graphs

- *Review of basic data structures:* lists, trees, search trees, graphs
- *Basic geometric primitives*: intersections of two line segments, polygon centroid, position of a point with respect to an oriented line, etc.
- *Geometric algorithms*: point-in-polygon, line segment intersections, polygon overlay
- *Processing and analysis of point data:*
    - Hierarchical spatial indexes: quadtrees and kd-trees
    - Voronoi diagrams
    - Algorithms for nearest neighbor, and range searching
    - Clustering algorithms: hierarchical nearest neighbor, and k-means
- *Surface and field modeling (terrain models):*
    - TINs: data structures, Delaunay triangulation, Delaunay triangulation algorithms
    - Raster models: regular grids, gridding and deterministic interpolation algorithms
    - Computing terrain morphology: slope, aspect, curvature, critical points
- *Drainage modeling on terrains*: watershed computation on grids and TINs
- *Visibility on terrains and applications:* algorithms for viewshed and for horizon computation
- *Examples of applications to LiDAR (Light Detection And Ranging) data processing:*
    - Terrain reconstruction from LiDAR data.
    - Rooftop reconstruction from LiDAR data in urban environments.
    - Tree mapping and reconstruction in forest management.
    - Bathymetry and coast line reconstruction in coastal data processing and analysis.

Assessment and Grading

- *Mid-term* exam – 25%
- *Homework* – 10%
- *Project* – 30%
- *Final* exam – 25%

- *Class participation* –
10%

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. Class participation will include occasional short quizzes and other in-class activities.

The homework will consist of implementing some algorithm seen in class also through the use of existing open-source library for geospatial data. The project will consist of designing and implementing algorithms for processing and analyzing airborne or drone-based LiDAR data in the context of some specific application problem discussed in class. The project for graduate students will be defined by an individual consultation with the instructor. Graduate students will also have to complete a research paper describing the project with a review of the literature in the specific topic.

General Requirements

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. The students are strongly urged to attend and participate in all lectures since this will provide a basic understanding of the subject matter of the course. 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 on any required reading.

Students are expected to treat each other with respect. 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.

Academic Integrity

The University of Maryland, College Park has a nationally recognized Code of Academic

Integrity, administered by the Student Honor Council. This Code sets standards for academic integrity at Maryland for all undergraduate and graduate students. Students are responsible for upholding these standards for this course. It is very important for a student to be aware of the consequences of cheating, fabrication, facilitation, and plagiarism. Students are strongly advised to visit https://bsosundergrad.umd.edu/engagement/academic-integrity-honorf for more information. The Honor pledge must be included in every assignment and exam submitted by the students: "I pledge on my honor that I have not given or received any unauthorized assistance on this assignment/paper/examination."

Students with Disabilities

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 and no later than February 14, 2017. 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.

Medical Excuses

Any student who needs to be excused for an absence from a single lecture, recitation, or lab due to a medically necessitated absence shall: a) Make a reasonable attempt to inform the instructor of his/her illness prior to the class. b) Upon returning to the class, present their instructor with a self-signed note attesting to the date of their illness. Each note must contain an acknowledgment by the student that the information provided is true and correct. Providing false information to University officials is prohibited under Part 9(i) of the Code of Student Conduct (V-1.00 (B) University of Maryland Code of Student Conduct) and may result in disciplinary action. Any student who needs to be excused for a prolonged absence (2 or more consecutive class meetings), or for a Major Scheduled Grading Event, must provide written documentation of the illness from the Health Center or from an outside health's provider. This documentation must verify dates of treatment and indicate the timeframe that the student was unable to meet academic responsibilities. In addition, it must contain the name and phone number of the medical service provider to be used if verification is needed. No diagnostic information will ever be requested.

Exam Make Up Policy

The instructor is not under obligation to offer a substitute assignment or to give a student a make-up assessment for missing a Major Scheduled Grading Event unless the failure to

perform was due to an excused absence. A valid excused absence will need to be granted through the student presenting documentation from the Health Center or from an outside health care professional. This documentation must be submitted within one week of returning to classes and must include dates of incapacitation as well as the name and phone number of the health care provider. No diagnostic information shall be given. Once the period of incapacitation is over, the student must meet the missed academic responsibilities according to the requirements and specification set forth by the instructor.

CourseEvalUM

Participation in the evaluation of courses through CourseEvalUM is a responsibility of the student hold as a member of our academic community. The feedback is confidential and important to the improvement of teaching and learning at the University as well as to the tenure and promotion process. The date from which CourseEvalUM is open to complete evaluations will be announced by the University. Please go directly to the website (www.courseevalum.umd.edu) to complete evaluations by the requested date By completing all the evaluations each semester, a student will have the privilege of accessing online, at Testudo, the evaluation reports for the thousands of courses for which 70% or more students submitted their evaluation.