Department of Geography & Environmental Management

GEOG 474 Special Topics in Geography: Machine Learning in Geospatial Science Course Outline: Winter 2020

1. Course Information

- Class Location and Time: HH-139, Mondays, 8:30 - 11:20 am
- Instructor's Contact Information: Prof. Jonathan Li, Office: EV1-111, ext. 34504, E-mail: junli@uwaterloo.ca
- Office Hours: Mondays, 4:00 – 5:00 pm or by appointment.

2. Course Description

An in-depth study of current machine learning algorithms and their applications in geospatial science, with a focus on image processing and analysis. Topics may vary depending on students' interests, such as land use and land cover classification, change detection, building and road detection and extraction, using multiple sensory data including multispectral images, synthetic aperture radar (SAR) images, and LiDAR point clouds. Machine learning algorithms implanted using Python will be investigated and applied.

3. Prerequisite(s)

Prerequisite checking is the student's responsibility. The students must have taken at least one statistics course and a remote sensing course (e.g., ENVS178, ENVS278, GEOG316; GEOG 271, 371, or 471) and have enough knowledge in multivariate statistics and remote sensing as well as image processing skills.

4. Course Rationale and Objectives

Machine learning is a set of techniques that allow machines to learn from data and experience, rather than requiring humans to specify the desired behavior by hand. Over the past two decades, machine learning techniques have become increasingly central in both the geospatial science and geomatics technology industry. This course provides a broad introduction to some of the most commonly used ML algorithms. The first half of the course focuses on supervised learning, including nearest neighbours, decision trees, ensemble learning, and support vector machines (SVM). In the second half of the course, we then move on to unsupervised learning, focusing in particular on probabilistic models, probability models, Gaussian mixture model, and neural networks (e.g., CNN).

5. Programming and Computing Environment

Windows-based PCI Geoamtica and ENVI packages are available in the Graduate Computer Lab. More importantly, students are required to learn Python from scratch and later to use Python to complete assignments and a term project independently. GPU-based desktop computers for running deep learning algorithms are also available in EV1-345 but the students need the instructor's permission to access to EV1-345. However, you must be aware that this is not a programming training course. You will need take "Google's Python Class" at https://developers.google.com/edu/python to learn Python from scratch!

6. Course Materials

This course does not require the purchase of any textbook. Instead, a few small readings may be assigned if the need arises. You may find relevant resources that are freely available online at https://github.com/loveunk/Deep-learning-books. We will try to provide links on a lecture-by-lecture basis.

The following three freely available online textbooks will be posted in LEARN for you to download:

- Bill Lubanovic: "Introducing Python", 2015
- Andreas C. Müller, Sarah Guido: "Introduction to Machine Learning with Python", 2016
- Christopher Bishop: "Pattern Recognition and Machine Learning", 2006

7. Course Evaluation

There is no exam in this course. In lieu of exams, the students will complete a substantial research paper on a topic of your choice. The students will need to propose a topic to the instructor and apply remotely sensed data and advanced digital image analysis techniques to solve urban problems.

- **Three assignments:** **55%**
  - ✓ Assignment 1: Random Forest 15%
  - ✓ Assignment 2: Support Vector Machines 15%
  - ✓ Assignment 3: CNN 25%
- **Two in-class tests:** **45%**
  - ✓ In-class Test-1: 1 hour, focused on 1st half of course 20%
  - ✓ In-class Test-2: 1.5 hrs, focused on 2nd half of course 25%

8. Tentative Schedule (*Note: Week Feb 17-21, 2020: Reading Week, no class scheduled

Week/Date	Topic	Lab/Assessment Activity
1/Jan 6	Course Overview and Introduction	
2/Jan 13	Introduction to Python	Practicing with Python
3/Jan 20	k-Nearest Neighbour	Practicing with Python, continued
4/Jan 27	Decision Trees	A1: Random Forest with Python
5/Feb 3	Support Vector Machines Tutorial #1 for In-class Test-1	A1: continued
6/Feb 10	**In-class Test-1,** Ensemble Learning	A2: SVM with Python
7/Feb 17	**Reading Week: No class or lab**	
8/Feb 24	Probabilistic Models	A2: continued
9/Mar 2	Neural Networks	A3: CNN with Python
10/Mar 9	Introduction to Deep Leaning	A3: continued
11/Mar 16	GMM and EM	A3: continued
12/Mar 23	Tutorial #2 for In-class Test-2	A3: continued
13/Mar 30	**In-class Test-2**	A3: continued

Tests, Calculators and Crib Sheets: Two compulsory non-cumulative tests (held in class) will gauge student progress on material covered up to and including the class before the test. The tests will comprise multiple-choice and true-false questions, and short-answer questions. Students are permitted to bring one page (double-sided, US Letter size 8.5" x 11") of hand-written study notes (aka a "crib sheet") with them into each test. Your crib sheet will be subject to inspection by exam proctors, and may be collected at the end of the test. Hand-written notes only: photocopies are not permitted.

9. Requesting Academic Consideration from the Associate Dean, Undergraduate Studies (5 January 2018)

Academic Integrity: In order to maintain a culture of academic integrity, members of the University of Waterloo community are expected to promote honesty, trust, fairness, respect and responsibility. www.uwaterloo.ca/academicintegrity/. Students who are unsure what constitutes an academic offence are requested to visit the on-line tutorial at: http://www.lib.uwaterloo.ca/ait/

Research Ethics: Please also note that the 'University of Waterloo requires all research conducted by its students, staff, and faculty which involves humans as participants to undergo prior ethics review and clearance through the Director, Office of Human Research and Animal Care (Office). The ethics review and clearance processes are intended to ensure that projects comply with the Office's Guidelines for Research with Human Participants (Guidelines) as well as those of provincial and federal agencies, and that the safety, rights and welfare of participants are adequately protected. The Guidelines inform researchers about ethical issues and procedures which are of concern when conducting research with humans (e.g. confidentiality, risks and benefits, informed consent process, etc.). If the development of your research

proposal consists of research that involves humans as participants, the please contact the course instructor for guidance and see: www.research.uwaterloo.ca/ethics/human/

Note for students with disabilities: The Office for Persons with Disabilities (OPD), located in Needles Hall, Room 1132, collaborates with all academic departments to arrange appropriate accommodations for students with disabilities without compromising the academic integrity of the curriculum. If you require academic accommodations to lessen the impact of your disability, please register with the OPD at the beginning of each academic term.

Religious Observances: Please inform the instructor at the beginning of term if special accommodation needs to be made for religious observances that are not otherwise accounted for in the scheduling of classes and assignments.

Grievance: A student who believes that a decision affecting some aspect of his/her university life has been unfair or unreasonable may have grounds for initiating a grievance. Read Policy 70 - Student Petitions and Grievances, Section 4, www.adm.uwaterloo.ca/infosec/Policies/policy70.htm. When in doubt, contact your Undergraduate Advisor for details.

Discipline: A student is expected to know what constitutes academic integrity, to avoid committing academic offence, and to take responsibility for his/her actions. A student who is unsure whether an action constitutes an offense, or who needs help in learning how to avoid offenses (e.g., plagiarism, cheating) or about "rules" for group work/collaboration should seek guidance from the course professor, academic advisor, or the Undergraduate Associate Dean. For information on categories of offences and types of penalties, students should refer to Policy 71, Student Discipline, www.adm.uwaterloo.ca/infosec/Policies/policy71.htm. For typical penalties, check Guidelines for Assessment of Penalties, www.adm.uwaterloo.ca/infosec/guidelines/penaltyguidelines.htm

Appeals: A decision made or penalty imposed under Policy 70 - Student Petitions and Grievances (other than a petition) or Policy 71 – (Student Discipline) may be appealed if there is a ground. A student who believes he/she has a ground for an appeal should refer to Policy 72. See: www.adm.uwaterloo.ca/infosec/Policies/policy72.htm

Consequences of Academic Offences: ENV students are strongly encouraged to review the material provided by the university's Academic Integrity office, see: http://uwaterloo.ca/academicintegrity/Students/index.html

Turnitin: Plagiarism detection software (Turnitin) will be used to screen assignments on this course. This is being done to verify use of all material and sources in assignments is documented. In the first lecture of the Term, details will be provided about the arrangements for the use of Turnitin. NOTE: Students may request an alternative to Turnitin, which is to prepare an annotated bibliography for each assignment. For advice on how to prepare an annotated bibliography, see: http://www.lib.sfu.ca/help/writing/annotated-bibliography.