Western University
Faculty of Engineering
Department of Civil and Environmental Engineering

CEE 9730 – Data science for civil engineers: geotechnical applications (with CEE 4420A)

COURSE OUTLINE 2022-2023

DESCRIPTION

The objective of the course is for students to develop a hands-on understanding of the field of data science, with a focus on opportunities and more importantly limitations pertaining to applications in geotechnical engineering. Students will work in groups on two projects over the course of the term, which will be scoped with guidance from the course instructor. The projects will be peer-assessed by other groups, who will grade each other on a) legibility and quality of code and dataset as well as corresponding documentation; b) a presentation on the construction of the dataset and performance of the algorithm. Topics include introduction to Python programming and the Numpy, scikit-learn, and PyTorch package, definitions, learning algorithms, unsupervised algorithms, feature engineering, various flavours of deep learning, and generative adversarial networks. Each topic will be introduced alongside recent research in the field of geotechnical engineering where possible.

ENROLLMENT RESTRICTIONS

All course outlines must include one of the following two statements regarding enrollment restrictions:

Enrollment in this course is restricted to graduate students in Civil and Environmental Engineering, as well as any student that has obtained special permission to enroll in this course from the course instructor as well as the Graduate Chair (or equivalent) from the student's home program.

INSTRUCTOR CONTACT INFORMATION

Course instructor: Bing Li
Email address: bing.li@uwo.ca
Office: SEB 3010C
Office hours: After tutorials

COURSE FORMAT

In-person Powerpoint presentations. Grading comes from 2 course projects.

TOPICS

Topic #	Description	Learning Activities	Tentative timeline
1: Introduction	- Introduction to Python and data science - Supervised, unsupervised, semi-supervised learning	• Powerpoint lectures • Tutorial 1: "hello world" in Python • Zoom office hours	Week 1
2: Definitions	- Notation - Baye's rule - Hyperparameters - Classification vs regression	• Powerpoint lectures • Tutorial 2: Numpy, Scikit-learn, Pytorch packages • Zoom office hours	Week 2
3: "Classical" learning algorithms	- Logistic regression - Decision trees - Support vector machines - Nearest neighbours	• Powerpoint lectures • Project 1 • Zoom office hours	Week 3
4: "Learning" algorithms	- Gradient descent - Loss function - Overfitting vs underfitting - Training vs testing vs validation - Missing features	• Powerpoint lectures • Project 1 • Zoom office hours	Week 4
Presentation and reports due for project 1			
5: Feature engineering	- Normalization - Binning - One-hot encoding - Performance metrics - Validation	• Powerpoint lectures • Project 1 • Zoom office hours	Week 5
6: Deep learning	- Neural networks - Back propagation	• Powerpoint lectures • Project 1 • Zoom office hours	Week 6
7: Flavours of deep learning	- Convolutional neural networks - Recurrent neural networks	• Powerpoint lectures • Project 2 • Zoom office hours	Week 7
8: Generational adversarial networks	- Discriminative vs. Generative Modeling - Conditional GANs	• Powerpoint lectures • Project 2 • Zoom office hours	Week 8
Reading week (no class)			Week 9
9: Unsupervised learning	- K-means - PCA - ICA	• Powerpoint lectures • Project 2 • Zoom office hours	Week 10
End of lectures to allow students more time for project 2			
Presentation and reports due for project 2 at end of term			

POTENTIAL PROJECT TOPICS

The following are possible project ideas, but students are also encouraged to develop their own ideas following their interests.

Project 1:

SVM+decision tree using TC304 dataset from KK Phoon group to regress for rock and soil site parameters. Students will attempt to predict stress-strain-strength material properties e.g. Su, E, UCS from indicators such as lithology/soil type, depth, LL/PL/PI, Q, GSI, RMR. The students will have to overcome the issue of incompletely labelled data, as is the case in many geotechnical projects.

Project 2 option 1:

Time series prediction with MLRA data (series of pore pressure sensors). The students will attempt to predict the pore pressure in these sensors using air temperature, rainfall, and air pressure. Could be done using decision tree or RNN.

Project 2 option 2:

Image classification of cracked vs uncracked rocks. Likely requires CNN, data will come from MIT rock mechanics research group high-speed data. The students will be provided with high-speed video images of a rock undergoing fracturing from uniaxial loading, students will develop a classifier for whether there is a crack on the rock. Students will additionally attempt to label the regions corresponding to cracked rock.

SPECIFC LEARNING OUTCOMES

Degree Level Expectation	Weight	Assessment Tools	Outcomes
Depth and breadth of knowledge	30%	• Projects	• Understanding of advanced concepts and theories • Awareness of important current problems in the field of study • Understanding of computational and/or empirical methodologies to solve related problems
Research & scholarship	10%	• Project	• Ability to conduct critical evaluation of current advancements in the field of specialization • Ability to conduct coherent and thorough analyses of complex problems using established techniques/principles and judgment
Application of knowledge	30%	• Projects	• Ability to apply knowledge in a rational way to analyze a particular problem • Ability to use coherent approach to design a particular engineering system using existing design tools
Professional capacity / autonomy	5%	• Project	• Awareness of academic integrity • Ability to implement established procedures and practices in the coursework • Defends own ideas and conclusions • Integrates reflection into his/her learning process

Communication skills	15%	• Project	• Ability to communicate (oral and/or written) ideas, issues, results and conclusions clearly and effectively
Awareness of limits of knowledge	10%	• Project	• Awareness of the need of assumptions in complex scientific analyses and their consequences • Understanding of the difference between theoretical and empirical approaches • Ability to acknowledge analytical limitation due to complexity of practical problems

ASSESSMENTS

Assessment	Tentative Due Date	Weight
Project 1 documentation of code and dataset	21st October	20%
Project 1 presentation	21st October	20%
Project 2 documentation of code and dataset	9th December	30%
Project 2 presentation	9th December	30%

Activities in which collaboration is permitted:

- Students are encouraged to work on projects in groups of three

Activities in which students must work alone (collaboration is not permitted):

- N/A

REQUIRED TEXTBOOK

N/A

OPTIONAL COURSE READINGS

Neural Networks and Deep Learning by Michael Nielsen
The Hundred-Page Machine Learning Book by Andriy Burkov
https://towardsdatascience.com is an excellent general resource
The International Society for Soil Mechanics and Geotechnical Engineering maintains an excellent archive of active research in this area (http://140.112.12.21/issmge/ml_ref.htm)

CHEATING, PLAGIARISM/ACADEMIC OFFENCES

Academic integrity is an essential component of learning activities. Students must have a clear understanding of the course activities in which they are expected to work alone (and what working alone implies) and the activities in which they can collaborate or seek help; see information above and ask instructor for clarification if needed. Any unauthorized forms of help-seeking or collaboration will be considered an academic offense. University policy states that cheating is an academic offence. If you are caught cheating, there will be no second warning. Students must write their essays and assignments in their own words. Whenever students take an idea or a passage of text from another author, they must acknowledge their debt both by using quotation marks where appropriate and by proper referencing such as footnotes or citations. Plagiarism is a major academic offence. Academic offences are taken seriously and attended by academic penalties which may include expulsion from the program. Students are directed to read the appropriate policy,

specifically, the definition of what constitutes a Scholastic Offence at the following website: https://www.uwo.ca/univsec/pdf/academic_policies/appeals/scholastic_discipline_grad.pdf

All required papers may be subject to submission for textual similarity review to the commercial plagiarism-detection software under license to the University for the detection of plagiarism. All papers submitted for such checking will be included as source documents in the reference database for the purpose of detecting plagiarism of papers subsequently submitted to the system. Use of the service is subject to the licensing agreement, currently between The University of Western Ontario and Turnitin.com (http://www.turnitin.com).

CONDUCT

Students are expected to follow proper etiquette to maintain an appropriate and respectful academic environment. Any student who, in the opinion of the instructor, is not appropriately participating in course activities and/or is not following the rules and responsibilities associated with the course activities, will be reported to the Associate Dean (Graduate) (after due warning has been given). On the recommendation of the Department concerned, and with the permission of the Associate Dean (Graduate), the student could be debarred from completing the assessment activities in the course as appropriate.

HEALTH/WELLNESS SERVICES

As part of a successful graduate student experience at Western, we encourage students to make their health and wellness a priority. Western provides several health and wellness related services to help you achieve optimum health and engage in healthy living while pursuing your graduate degree. Information regarding health- and wellness-related services available to students may be found at http://www.health.uwo.ca/.

Students seeking help regarding mental health concerns are advised to speak to someone they feel comfortable confiding in, such as their faculty supervisor, their program director (graduate chair), or other relevant administrators in their unit. Faculty of Engineering has a Student Wellness Counsellor. To schedule an appointment with the counsellor, contact Kristen Edwards (khunt29@uwo.ca) via confidential email and you will be contacted by our intake office within 48 hours to schedule an appointment.

Students who are in emotional/mental distress should refer to Mental Health@Western: http://www.uwo.ca/uwocom/mentalhealth/ for a complete list of options about how to obtain help.

SICKNESS

Students should immediately consult with the Instructor (for a particular course) or Associate Chair (Graduate) (for a range of courses) if they have problems that could affect their performance. The student should seek advice from the Instructor or Associate Chair (Graduate) regarding how best to deal with the problem. Failure to notify the Instructor or the Associate Chair (Graduate) immediately (or as soon as possible thereafter) will have a negative effect on any appeal. Obtaining appropriate documentation (e.g., a note from the doctor) is valuable when asking for accommodation due to illness.

Students who are not able to meet certain academic responsibilities due to medical, compassionate or other legitimate reason(s), could request for academic consideration. The Graduate Academic Accommodation Policy and Procedure details are available at:
https://www.eng.uwo.ca/graduate/current-students/academic-support-and-accommodations/index.html

ACCESSIBLE EDUCATION WESTERN (AEW)

Western is committed to achieving barrier-free accessibility for all its members, including graduate students. As part of this commitment, Western provides a variety of services devoted to promoting, advocating, and accommodating persons with disabilities in their respective graduate program. Graduate students with disabilities (for example, chronic illnesses, mental health conditions, mobility impairments) are strongly encouraged to register with Accessible Education Western (AEW): http://academicsupport.uwo.ca/accessible_education/index.html

AEW is a confidential service designed to support graduate and undergraduate students through their academic program. With the appropriate documentation, the student will work with both AEW and their graduate programs (normally their Graduate Chair and/or Course instructor) to ensure that appropriate academic accommodations to program requirements are arranged. These accommodations include individual counselling, alternative formatted literature, accessible campus transportation, learning strategy instruction, writing exams and assistive technology instruction.