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 packages
- 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.

Calendar Copy:
Application of Python programming, learning algorithms, unsupervised algorithms, feature engineering, deep learning and generative adversarial networks in geotechnical engineering.

Prerequisites:
2219A/B COMPUTATIONAL TOOLS FOR CIVIL ENGINEERS

Antirequisites:
None

Note: It is the student's responsibility to ensure that all Prerequisite and Corequisite conditions are met or that special permission to waive these requirements has been granted by the Faculty. It is also the student's responsibility to ensure that they have not taken a course listed as an Antirequisite. The student may be dropped from the course or not given credit for the course towards their degree if they violate the Prerequisite, Corequisite or Antirequisite conditions.

Contact Hours:
2 lecture hours/week (required); 2 tutorial hours/week;
Tutorials are not mandatory but students seeking assistance with projects or clarification on lecture material are strongly encouraged to attend.
Additional self-study: 4 hours/week.

Key Sessional Dates:
Classes begin: September 12, 2022
Fall Reading Week: October 31 – November 6, 2022;
Classes end: December 8, 2022;
Contingency plan for an in-person class pivoting to 100% online learning

In the event of a COVID-19 resurgence during the course that necessitates the course delivery moving away from face-to-face interaction, affected course content will be delivered entirely online, either synchronously (i.e., at the times indicated in the timetable) or asynchronously (e.g., posted on OWL for students to view at their convenience). The grading scheme will not change. Any remaining assessments will also be conducted online as determined by the course instructor.

Instructor:

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

Administrative Assistant: Sandra McKay (smckay@uwo.ca)

Textbook:

Other References:
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)

Students are responsible for checking the course OWL site (http://owl.uwo.ca) on a regular basis for news and updates. This is the primary method by which information will be disseminated to all students in the class.

All course material will be posted to OWL: http://owl.uwo.ca.

If students need assistance with the course OWL site, they can seek support on the OWL Help page. Alternatively, they can contact the Western Technology Services Helpdesk. They can be contacted by phone at 519-661-3800 or ext. 83800.

Units:
Both SI and FPS unit systems may be used in lectures, tutorials and examinations.

Specific Learning Objectives:
The lectures and tutorial assignments will prepare students to do the following [GA Indicator]:

1. Apply Python programming language for reading in, processing, and plotting large datasets [ET 2]
2. Identify and format appropriate input and output formats for a range of machine learning models [PA 1, PA 2]
3. Identify and implement appropriate machine learning models (decision trees, support vector machines, deep neural networks) for a given engineering problem [I 1]
4. Understand and differentiate between various buzzwords such as machine learning, data science, big data, artificial intelligence, etc. [KB 3]
5. Understand and critique limitations of various machine learning models [I 3, LL 1]
6. Work in teams to tackle geotechnical engineering datasets from data science perspective \([\text{ITW 1, ITW 2, ITW 3}]\)
7. Prepare, critique, present and document code and report on details and performance of machine learning models. \([\text{CS 1, CS 2, CS 3}]\)

The instructor may expand or revise material presented in the course as appropriate.

**TOPICS**

<table>
<thead>
<tr>
<th>Topic #</th>
<th>Description</th>
<th>Learning Activities</th>
<th>Tentative timeline</th>
</tr>
</thead>
</table>
| 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 |
|               |                                                                                           | Fall reading week                                                                   |                   |
| 8: Generational adversarial networks | - Discriminative vs. Generative Modeling  
- Conditional GANs | ● Powerpoint lectures  
● Project 2  
● Zoom office hours | Week 8 |
### 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.

### General Learning Objectives:

<table>
<thead>
<tr>
<th>Knowledge Base</th>
<th>E (I)</th>
<th>T</th>
<th>Impact on Society</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem Analysis</td>
<td>T</td>
<td></td>
<td>Ethics and Equity</td>
</tr>
<tr>
<td>Investigation</td>
<td>T</td>
<td></td>
<td>Economics and Project Management</td>
</tr>
<tr>
<td>Design</td>
<td></td>
<td></td>
<td>Life-Long Learning</td>
</tr>
</tbody>
</table>

E=Evaluate, T=Teach, I=Introduce; (I) = Introduction, (D) = Developing, (A) = Advanced level
Evaluation:
The final mark will be determined as follows:

<table>
<thead>
<tr>
<th>Assessment</th>
<th>Tentative Due Date</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project 1 documentation of code and dataset</td>
<td>21st October</td>
<td>20%</td>
</tr>
<tr>
<td>Project 1 presentation</td>
<td>21st October</td>
<td>20%</td>
</tr>
<tr>
<td>Project 2 documentation of code and dataset</td>
<td>9th December</td>
<td>30%</td>
</tr>
<tr>
<td>Project 2 presentation</td>
<td>9th December</td>
<td>30%</td>
</tr>
</tbody>
</table>

Note: Students must pass the final project to pass this course. Students who fail the final examination will be assigned the aggregate mark, as determined above, or 48%, whichever is less. Students who have failed this course previously must repeat all components of the course. No special permissions will be granted enabling a student to retain laboratory, assignment or test marks from previous years. Previously completed assignments and laboratories cannot be resubmitted.

1. Class projects:
Code and presentations will be submitted on specified date. Presentations will occur the following week. Extensions are to be negotiated with the course instructor, not the teaching assistants.

2. Use of English:
In accordance with Senate and Faculty Policy, students may be penalized up to 10% of the marks on all assignments, tests, and examinations for improper use of English. Additionally poorly written work with the exception of the final examination may be returned without grading. If resubmission of the work is permitted, it may be graded with marks deducted for poor English and/or late submission.

Cheating:
University policy states that cheating is a scholastic offence. The commission of a scholastic offence is attended by academic penalties that might include expulsion from the program. If you are caught cheating, there will be no second warning.

For more information on scholastic offenses, please see:
http://www.uwo.ca/univsec/handbook/appeals/scholastic_discipline_undergrad.pdf

Attendance:
Any student who, in the opinion of the instructor, is absent too frequently from class, laboratory, or tutorial periods will be reported to the Dean (after due warning has been given). On the recommendation of the Department concerned, and with the permission of the Dean, the student will be debarred from taking the regular final examination in the course.

Accommodation and Accessibility:

Religious Accommodation
When a course requirement conflicts with a religious holiday that requires an absence from the University or prohibits certain activities, students should request accommodation for their absence in writing at least two weeks prior to the holiday to the course instructor and/or the Academic Counselling office of their Faculty of Registration. Please consult University's list of recognized religious holidays (updated annually) at


Accommodation Policies
Students with disabilities are encouraged to contact Accessible Education, which provides recommendations for accommodation based on medical documentation or psychological and cognitive testing. The policy on Academic Accommodation for Students with Disabilities can be found at:

https://www.uwo.ca/univsec/pdf/academic_policies/appeals/Academic_Accommodation_disabilities.pdf.

**Conduct:**
Students are expected to arrive at lectures on time, and to conduct themselves during class in a professional and respectful manner that is not disruptive to others. Please turn off your cell phone before coming to a class, tutorial, quiz or exam. On the premises of the University or at a University-sponsored program, students must abide by the Student Code of Conduct:

http://www.uwo.ca/univsec/board/code.pdf

**Sickness and Other Problems:**
If you are unable to meet a course requirement due to illness or other serious circumstances, please follow the procedures below.

**Assessments worth 10% or more of the overall course grade:**

For work totalling 10% or more of the final course grade, you must provide valid medical or supporting documentation to the Academic Counselling Office of your Faculty of Registration as soon as possible. For further information, please consult the University’s medical illness policy at


The Student Medical Certificate is available at


Presentations will be rescheduled should a student present evidence of sickness or other problems for that day.

**Academic Policies:**
The website for Registrarial Services is http://www.registrar.uwo.ca.

In accordance with policy,

https://www.uwo.ca/univsec/pdf/policies_procedures/section1/mapp113.pdf,

the centrally administered e-mail account provided to students will be considered the individual’s official university e-mail address. It is the responsibility of the account holder to ensure that e-mail received from the University at their official university address is attended to in a timely manner.

**Scholastic offences** are taken seriously, and students are directed to read the appropriate policy, specifically, the definition of what constitutes a Scholastic Offence, at the following Web site:


**Support Services:**
Please visit the Western Engineering Undergraduate Services webpage for information on adding/dropping courses, academic considerations for absences, appeals, exam conflicts, and many other academic related matters: https://www.eng.uwo.ca/undergraduate/index.html

Students who are in emotional/mental distress should refer to Mental Health@Western (https://uwo.ca/health/) for a complete list of options about how to obtain help.

Western is committed to reducing incidents of gender-based and sexual violence and providing compassionate support to anyone who has gone through these traumatic events. If you have experienced sexual or gender-based violence (either recently or in the past), you will find information about support services for survivors, including emergency contacts at


To connect with a case manager or set up an appointment, please contact support@uwo.ca.

Please contact the course instructor if you require lecture or printed material in an alternate format or if any other arrangements can make this course more accessible to you. You may also wish to contact Accessible Education at

http://academicsupport.uwo.ca/accessible_education/index.html

if you have any questions regarding accommodations.

Learning-skills counsellors at the Student Development Centre (https://learning.uwo.ca) are ready to help you improve your learning skills. They offer presentations on strategies for improving time management, multiple-choice exam preparation/writing, textbook reading, and more. Individual support is offered throughout the Fall/Winter terms in the drop-in Learning Help Centre, and year-round through individual counselling.

Western University is committed to a thriving campus as we deliver our courses in the mixed model of both virtual and face-to-face formats. We encourage you to check out the Digital Student Experience website to manage your academics and well-being: https://www.uwo.ca/se/digital/.

Additional student-run support services are offered by the USC, https://westernusc.ca/services/.

**Course Breakdown:** (Values given in accreditation units)
Engineering Science = 100%
INSTRUCTIONS FOR STUDENTS UNABLE TO WRITE TESTS OR EXAMINATIONS OR SUBMIT ASSIGNMENTS AS SCHEDULED

Academic Consideration provides students with consistent, fair, and academically appropriate consideration, when they are unable to complete some component of a course due to extenuating circumstances. If you have missed or will miss a course-related component (e.g. laboratory or tutorial) or a course-related assessment (e.g. quiz) you may be eligible to request an Academic Consideration to make arrangements to complete the missed course work at a later time.

Academic Consideration for course-related components and assessments may include:
- Class Attendance/Tutorial Attendance/Laboratory Attendance
- Midterm Exam/Test
- Presentation/Essay/Assignment
- Quiz

There are three ways you can request academic consideration:
- Self-Reported Absence
- Medical Absence
- Non-Medical Absence

The nature of your circumstance/request will determine which route to pursue in requesting Academic Consideration. Factors affecting your eligibility for consideration or which method would be most appropriate for you to submit your request are:
- The duration of time needed.
- The number of Self-Reported Absences submitted within the Term
- The credit weight of the course-related component

Tip: Remember to send notification of your absence within the acceptable timeframe for your type of absence. Make sure to communicate with your instructor about your absence and to plan for completing any missed coursework.

Medical Absence and Non-Medical Absence – Use the Accommodation Consideration Request Form. Please note: If the assessment you are missing is less than 10% of your final grade, your form will be approved by the CEE department; if it worth 10% or more, your form will be approved by Engineering Undergraduate Services.

- Student Medical Certificate to be attached to Accommodate Request Form if absence is due to illness.
- Extended Absences – two weeks or more. Please make an appointment with your Academic Counsellor in Engineering Undergraduate Services (https://www.eng.uwo.ca/undergraduate/academic-support-and-accommodations/academic-counselling.html)
- In Case of Serious Illness of a Family Member: Provide a Student Medical Certificate to your family member's physician to complete and submit it with your Accommodation Consideration Request.
- In Case of a Death: Obtain a copy of the death certificate or the notice provided by the funeral director's office. You must include your relationship to the deceased and submit it with your
Accommodation Consideration Request

- For other Extenuating Circumstances: Please complete the Accommodation Consideration Request Form with an explanation and any documentation.

Final Examinations

If you are unable to write a final examination, you should contact Undergraduate Services to request permission to write a Special Examination.

In order to receive permission to write a Special Examination, you must fill out the Academic Consideration Request form AND the Application for a Special Exam form. If approved, the Undergraduate Services Office will then notify the course instructor(s) and if it is an Engineering exam(s) you missed, reschedule the examination(s) on your behalf. Students writing examinations for outside engineering courses (ie. Applied Math, Computer Science, Physics, etc) will need to check with that department to find out the date, time & location of their exam(s).

Please note: It is the student's responsibility to check the date, time, and location of the special examination.

You will need to provide supporting documentation explaining the reason for your absence. If you are ill and visit a doctor, they will need to fill out the Student Medical Certificate. You will upload this documentation in the Academic Consideration Request Form.

The following circumstances are not considered grounds for missing a final examination or requesting special examinations: common cold, sleeping in, misreading timetable and travel arrangements.

Additional Resources

- To connect with health and wellness resources on campus visit: https://www.uwo.ca/health/
- To book an appointment with psychological services visit: https://www.uwo.ca/health/psych/index.html

Calendar References: Check these regulations in your Western Academic Calendar available at www.westerncalendar.uwo.ca.

Self-Reporting Absences
Absences Due to Illness
Academic Accommodations for Students with Disabilities
Academic Accommodations for Religious or Holy Days
Course Withdrawals
Examinations
Scheduling of Term Assignments
Scholastic Offences
Student Medical Certificate
Engineering Academic Regulations

Note: These instructions apply to all students registered in the Faculty of Engineering regardless of whether the courses are offered by the Faculty of Engineering or other faculties in the University.

Contact Information: