Western University
Faculty of Engineering
Department of Electrical and Computer Engineering

SE 4460A: Machine Learning Fundamentals and Design for Engineers
Course Outline 2021-2022

Description: The objective of this course is to introduce students to the fields of Machine Learning and Data Science. Through this course, the students will learn various algorithms and how they are implemented to solve real-world problems. Students will get hands-on experience in implementing these algorithms using various programming languages and platforms.

Instructor: Dr. Abdallah Shami, P.Eng.
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Consultation hours: Wednesday: 11:30 am – 1:30 pm

Academic Calendar Copy: The objective of this course is to introduce students to the fields of Machine Learning and Data Science. The students will learn various algorithms and how they are implemented to solve real-world problems. Students will get hands-on experience in implementing these algorithms using various programming languages and platforms.

Contact Hours: 3 lecture hours per week, 2 laboratory hours per week, 1 tutorial hours per week, 0.5 course.

Antirequisite: Data Science 3000A/B, Computer Science 4414A/B.

Prerequisites: Engineering Science 1036A/B, Applied Mathematics 1411A/B, Statistical Sciences 2141A/B or Statistical Sciences 2143A/B.

Co-requisite: NA

Unless you have either the requisites for this course or written special permission from your Dean to enroll in it, you will be removed from this course and it will be deleted from your record. This decision may not be appealed. You will receive no adjustment to your fees in the event that you are dropped from a course for failing to have the necessary prerequisites.

CEAB Academic Units: Engineering Science 65%, Engineering Design 35%.

Required Textbook:

- **HTF**: Hastie, Tibshirani, Friedman. The Elements of Statistical Learning. New York: Springer. [Free: https://web.stanford.edu/~hastie/ElemStatLearn/]
- **JWHT**: James, G., Witten, D., Hastie, T., & Tibshirani, R. (2013). An introduction to statistical learning with applications in R. New York: Springer. [Free through Western]
- **MLPP**: Murphy, K. P. (2012). Machine Learning: a Probabilistic Perspective. MIT press.[Free: https://www.cs.ubc.ca/~murphyk/MLbook/]
- **BSH**: Legler and Roback. Broadening Your Statistical Horizons. [Free: https://bookdown.org/roback/bookdown-bysh/]

Other Required References:
Students must check OWL (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. Students are responsible for checking OWL on a regular basis.

General Learning Objectives (CEAB Graduate Attributes)

Knowledge Base		Use of Engineering Tools	A	Impact on Society and the Environment	
Problem Analysis	I	Individual and Team Work		Ethics and Equity	
Investigation		Communication Skills		Economics and Project Management	
Design		Professionalism		Life-Long Learning	

[Please use letter **I**, **D** or **A** for each attribute. **I** – The instructor will introduce the topic at the level required. It is not necessary for the student to have seen the material before. **D** – There may be a reminder or review, but the student is expected to have seen and been tested on the material before taking the course. **A** – It is expected that the student can apply the knowledge without prompting (e.g. no review).]

Topics and Specific Learning Objectives

1. Supervised Learning and Model Fitting [PA2, PA3, ET1, ET2]

At the end of this section, students will be able to:

a. Define in words terminology related to machine learning and data analytics
b. Define gradient descent mathematically
c. Define the various metrics used to evaluate machine learning models both in words and mathematically
d. Define in words and mathematically the Linear Regression (LR) algorithm
e. List various applications of LR algorithm
f. Implement LR algorithm

2. Statistics, Prediction, and Maximum Likelihood

At the end of this section, students will be able to:

a. Generate exploratory data analysis plots and summary statistics.
b. Use residual diagnostics to examine ordinary least squares assumptions.
c. Describe the concept of a likelihood, in words.
d. Know and apply the Principle of Maximum Likelihood for a simple example.
e. Construct a likelihood for a simple model

3. Classification and Multi-Class Problems [PA2, PA3, ET1, ET2]

At the end of this section, students will be able to:

a. Define the task of classification
b. Define in words and mathematically the Logistic Regression (LR) and Support Vector Machine (SVM) algorithms
c. List various applications of LR & SVM algorithm
d. Interpret estimated coefficients in LR and SVM.

e. Implement LR & SVM algorithms

4. **Estimating Performance and Quantifying Uncertainty**

At the end of this section, students will be able to:

a. Understand and Define in words and mathematically the following concepts/methods: Bias, Variance, Central Limit Theorem, Confidence Intervals, bootstrap method, prediction uncertainty, test error, and Bias-variance decomposition
b. Apply bootstrap method and confidence intervals in a simple context

5. Cross-validation, Model Selection and Regularization [PA2, PA3, ET1, ET2]

At the end of this section, students will be able to:

a. Understand the basic concepts, issues, assumptions and limitations in machine learning (e.g. base accuracy, overfitting, bias/variance, curse of dimensionality...).
b. Understand and apply various cross-validation, model selection and regularization techniques/algorithms

6. Decision Trees and Random Forest [PA2, PA3, ET1, ET2]

At the end of this section, students will be able to:

a. Describe the components and use of a decision tree.
b. Define in words and mathematically the Random Forest Algorithm
c. Implement Decision Trees and Random Forest algorithms/Models

7. Neural Networks [PA2, PA3, ET1, ET2]

At the end of this section, students will be able to:

a. Define in words and mathematically the Artificial Neural Network architecture
b. Approximate functions using this architecture
c. Implement this architecture along with backpropagation
d. Define in words and mathematically dropout regularization
e. List various applications of Artificial Neural Networks
f. Implement Artificial Neural Networks

8. Clustering and Hierarchical Clustering [PA2, PA3, ET1, ET2]

At the end of this section, students will be able to:

a. Define in words and mathematically clustering and hierarchal clustering algorithms
b. List various applications of these algorithms
c. Define in words and mathematically the k-Nearest Neighbour algorithm
d. Implement this algorithm

Evaluation

Course Component	Weight
Laboratory Assignments	30 %
Midterm Test	25 %
Participation Quizzes	5%
Final Examination	40 %

To obtain a passing grade in the course, a mark of 50% or more must be achieved on the final examination as well as in the laboratory. A final examination or laboratory mark < 50% will result in a final course grade of 48% or less.

Laboratory Assignments: There will be 8-10 laboratory assignments. All laboratory assignments have equal weights. Laboratory assignments are programming-based. Python programming language and various Python-based machine learning packages will be used in this course. Laboratory assignments will be released every Monday, with due dates on the following Monday at 5:00 pm, unless otherwise specified. **No late laboratory assignments will be accepted, but will be graded with 0%.** The laboratory assignment with the lowest grade will be dropped for every student. Therefore, no special accommodation for a single missed laboratory assignment will be given. A grade of 50% or higher on the laboratory assignments is required to pass the course.

Midterm Test: The midterm will cover concepts up to and including those covered up to this point. The midterm will include a practical component; each student will need a laptop to complete the midterm. Students will be given a data set and a set of practical data analytic problems to solve, similar to the structure of the Lab assignments. The exam is "open book & open web", meaning that students can access any notes or any documents on the web. Electronic communication with other people inside or outside the classroom is prohibited. There will be no rescheduling of the midterm test. If a student misses the midterm test, the weight assigned to the final examination may be adjusted accordingly; please read the ***Missed Midterm Examinations*** section below for more information. The Midterm Exam will be conducted in person. The date and location will be shared before the end of September.

Final Examination: The final examination will take place during the regular examination period. The final exam will cover concepts from the entire course and is in structure similar to the midterm exam. A grade of 50% or higher on the final examination is required to pass the course. The final examination will include a practical component; each student will need a laptop to complete the exam. The Final Exam will be conducted in person. Each student will need a laptop to complete the Final Examination.

Participation Pop Quizzes: Each student will need a laptop to complete the participation pop in-person quiz. Participation pop quizzes will be conducted during randomly selected classes throughout the semester. A pop quiz may include a concept as well as a practical component.

Late Submission Policy: No late submissions will be accepted; late submission will be graded with 0%.

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 (except 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.

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, and with the permission of the Dean, the student will be debarred from taking the regular final examination in the course.

COVID Contingency: In the event of a COVID-19 resurgence during the course that necessitates the course delivery moving away from face-to-face interaction, all remaining 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 at the discretion of the course instructor.

Absence Due to Illness or Other Circumstances: Students should immediately consult with the instructor or department Chair if they have any problems that could affect their performance in the course. Where appropriate, the problems should be documented (see the attached "Instructions for Students Unable to Write Tests or Examinations or Submit Assignments as Scheduled"). The student should seek advice from the instructor or department Chair regarding how best to deal with the problem. Failure to notify the instructor or department Chair immediately (or as soon as possible thereafter) will have a negative effect on any appeal.

For more information concerning medical accommodations, see the relevant section of the Academic Handbook:
http://www.uwo.ca/univsec/pdf/academic_policies/appeals/accommodation_medical.pdf

For more information concerning accommodations for religious holidays, see the relevant section of the Academic Handbook:
http://www.uwo.ca/univsec/pdf/academic_policies/appeals/accommodation_religious.pdf

Missed Midterm Examinations: If a student misses a midterm examination, she or he must follow the Instructions for Students Unable to Write Tests and provide documentation to Undergraduate Services Office within 24 hours of the missed test. If accommodation is granted, the department will decide whether to provide a make-up test or allow reweighting of the test, where reweighting means the marks normally allotted for the midterm will be added to the final exam. If no reasonable justification for missing the test can be found, then the student will receive a mark of zero for the test.

If a student is going to miss the midterm examination for religious reasons, they must inform the instructor in writing within 48 hours of the announcement of the exam date or they will be required to write the exam.

Cheating and Plagiarism: Students must write their essays and assignments in their own words. Whenever students take an idea or a passage from another author, they must acknowledge their debt both by using quotation marks where appropriate and by proper referencing such as footnotes or citations. University policy states that cheating, including plagiarism, is a scholastic offence. The commission of a scholastic offence is attended by academic penalties, which might include expulsion from the program. If you are caught cheating, there will be no second warning.

All required papers may be subject to submission for textual similarity review to commercial plagiarism-detection software under license to the University for the detection of plagiarism. All papers submitted will be included as source documents on 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).

Scholastic offences are taken seriously and students are directed to read the appropriate policy, specifically, the definition of what constitutes a Scholastic Offence, in the relevant section of the Academic Handbook:
http://www.uwo.ca/univsec/pdf/academic_policies/appeals/scholastic_discipline_undergrad.pdf

Policy on Repeating All Components of a Course: Students who are required to repeat an Engineering course 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 by the student for grading in subsequent years.

Internet and Electronic Mail: Students are responsible for regularly checking their Western e-mail and the course web site (https://owl.uwo.ca/portal/) and making themselves aware of any information that is posted about the course.

Accessibility: Please contact the course instructor if you require material in an alternate format or if any other arrangements can make this course more accessible to you. You may also wish to contact Services for Students with Disabilities (SSD) at 519-661-2111 ext. 82147 for any specific question regarding an accommodation.

Support Services: Office of the Registrar, http://www.registrar.uwo.ca/
Student Development Centre, http://www.sdc.uwo.ca/
Engineering Undergraduate Services, http://www.eng.uwo.ca/undergraduate/
USC Student Support Services, http://westernusc.ca/services/

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