MSAI-349: MACHINE LEARNING

Fall 2025

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Teaching Assistant:
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Peer Mentor: TBA

Place: Tech, Lecture Room 4
Time: Tuesdays and Thursdays, 3:30PM to 4:50PM

Course Description: Machine Learning is "the study of computer programs that improve automatically with experience" according to Tom Mitchell, author of the book Machine Learning. This overview course covers the fundamentals of machine learning, including classification, regression, model training, and evaluation across various algorithms. The course aims to give you a foundational understanding of machine learning concepts from an intuitional and mathematical perspective. You will exercise this material on multiple homework assignments (coding and free response question answering), a final exam and a final group project.

Course Goals: This course will familiarize students with machine learning algorithms, optimization techniques, and evaluation metrics. After completing the course, students should be able to apply fundamental mathematical and analysis constructs to novel problems and algorithms.

Office Hours: Recurring time to be determined.

Materials: No textbook required. See lecture slides for recommended resources.

Prerequisites: Working knowledge of Python, linear algebra, statistics and single variable calculus.

Grading Policy: Grades are assigned using the standard scale (given in the "introduction" lecture notes), so 93- 100 points is an A, 90-93 points is an A-, etc. Points will be allocated as follows:

HW #1: Decision Trees	10 pts
HW #2: K-Means Clustering	10 pts
HW #3: Gradient Descent	10 pts
HW #4: Neural Networks	10 pts
Final Project	30 pts
Final Exam	30 pts
Total	100 pts

Students will form groups of three students for the homework assignments and the final project. Students in smaller groups will be assigned to other groups to meet these guidelines. Groups should remain static for the quarter.

There are four homework assignments for the course. Each assignment will consist of (i) a coding part in which the group will implement the specified algorithm in Python and (ii) a short question and answer part in which the group will demonstrate their understanding of the material. All group members should participate in all aspects of the homework assignments -- allocating specific activities to individual group members is inconsistent with the academic integrity policy. If some group members are not contributing, you are responsible for promptly bringing this to my attention.

There is no tolerance for academic dishonesty. Your code and answers must be your group's work. We will use a combination of automated and manual methods for comparing your code and free-response answers to that of other groups and if we find sufficiently suspicious similarities between your answers and those of another group, you will both be reported for a suspected violation. We will also check your submission against materials available on the internet and materials produced by generative AI. If a teaching assistant, peer mentor, or written resource provides you with substantial help, you must acknowledge that help in your assignment submission. If you're unsure of the academic integrity policies, ask for help; we can help you avoid breaking the rules, but we can't un-report a suspected violation.

The final project provides the opportunity for you to undertake an in-depth exploration of a topic that may interest you. It accounts for approximately thirty percent of your grade. Final projects can be applied or research-focused on a topic of your choosing. I am available to discuss potential topics and project parameters. The final projects will consist of three deliverables: (a) a project proposal, (b) preliminary results and (c) a presentation or short paper. The proposal is typically one page or less, and describes the project, anticipated data source(s), and proposed machine learning techniques. Preliminary results are due approximately three weeks before the presentation to allow for feedback and time for analysis. The final project will culminate in either a 20-minute presentation or a 3-page paper that highlights your findings.

All group members should participate in all aspects of the project. If all group members are not contributing, you are responsible for promptly bringing this to our attention. There may be a peer assessment component to your final project grade.

Other Class Policies:
Your health is more important than coursework. Ask for help whenever you need it. We are committed to fostering a safe and welcoming environment for all. If you need help navigating these resources, please ask. In addition to the University policies below, please pay particular attention to the following:

- You are responsible for making me aware promptly of any accommodation that you may have through AccessibleNU so that they can be implemented appropriately.
- Video or audio recordings are not permitted.
- Students are strongly encouraged to attend class in-person,
- Students are expected to adhere to the University's Academic Integrity Policy.

Calendar (Subject to Change)**:**

Week #1: Introduction and Decision Trees

- Introductory remarks and class policies
- Machine learning in a nutshell
- Attribute-based representations and decision trees
- Learning decision trees with entropy and information gain

Week #2: Decision Trees (cont.) and Distance Metrics

- ID3 algorithm, how to avoid over-fitting and pruning
- Random forests and regression
- Final project objectives and recommendations
- Distance metrics

Week #3: Nearest Neighbors and K-Means Clustering
- K-nearest neighbors algorithm
- K-means clustering

HW #1: Decision Trees Due

Week #4: Regression, Linear Discriminants and Perceptrons
- Linear and polynomial regression
- Linear discriminants and decision boundaries
- Perceptron algorithm and logistic regression

Final Project: Proposals Due

Week #5: Neural Networks I
- Gradient descent, objective functions and regularization
- Feed forward neural network architecture
- Linear transformations, activation functions and output layers

HW #2: KNN and K-Means Due

Week #6: Neural Networks II
- Back propagation and differentiation rules
- Detailed walk-thru of a feed forward neural network
- Calculation graphs and parallel computation

Week #7: Hypothesis Testing and Gaussian Mixture Models
- Error estimates, normal distribution, t-tests, cross validation, evaluation metrics
- Parametric distribution, EM algorithm, multi-variate distributions
- Gaussian mixture models

HW #3: Gradient Descent Due

Week #8: Language Modeling
- Introduction of language models and natural language processing tasks
- Embedding spaces and next token prediction
- Feed forward neural network language model
- Decoding and text generation

HW #4: Neural Networks Due

Week #9: Miscellaneous Topics
- Recurrent architectures, GANs, convolution neural networks
- Support vector machines, active learning, boosting

Final Project: Preliminary Results Due

Week #10: Review and Thanksgiving Break
- Catch-up
- Course review

Week #11: Review and Final Exam
- Course Review
- In-person final exam

Finals Week:
- Final project presentations

Final Project: Presentation or Paper Due

University Policy Statements

Academic Integrity

Students enrolled in Northwestern courses are required to comply with Northwestern's academic integrity policy. All papers submitted for credit in this course must be submitted electronically unless otherwise instructed by the professor. Your written work may be tested for plagiarized content. Any form of cheating, including improper use of content generated by artificial intelligence, constitutes a violation of Northwestern's academic integrity policy. To download Academic Integrity: A Basic Guide go to: https://www.northwestern.edu/provost/policies procedures/academic-integrity/index.html

Academic Support and Learning Advancement

Most Northwestern students find their coursework especially challenging at times. If you are experiencing challenges related to your academic work, you are encouraged to take advantage of resources available through Academic Support and Learning Advancement. They offer advice on learning strategies, consultations to help you pinpoint difficulties and plan solutions, peer-facilitated tutoring and study groups in selected courses, group and individual peer coaching, and dinner discussions with faculty on navigating your academic work.

Accessibility

Northwestern University is committed to providing a supportive environment for students with disabilities. Should you anticipate or experience disability-related barriers in the academic setting, please contact AccessibleNU to move forward with the university's established accommodation process. If you already have established accommodations with AccessibleNU, please let your instructor know as soon as possible, preferably within the first two weeks of the term, so we can work with you to implement your disability accommodations. Disability information, including academic accommodations, is confidential under the Family Educational Rights and Privacy Act.

Course Details Subject to Change

Please note that the specifics of a course syllabus are subject to change in the case of unforeseen circumstances. Instructors will notify students of any changes as soon as possible. Students will be responsible for abiding by the changes.

Exceptions to Class Modality

For courses noted as only occurring in-person, individual students will not be granted permission to attend remotely except as the result of an Americans with Disabilities Act (ADA) accommodation as determined by AccessibleNU. Should public health recommendations prevent in-person classes from being held on a given day, the instructor or the university will notify students.

Providing Display/Preferred Names and Pronouns

Northwestern community members can change their personal information by logging into NUValidate and selecting the "Edit Online Directory Information" tile. Any updates to your display name and pronouns will be visible to your instructor within a few days. For additional information visit: https://www.northwestern.edu/diversity/initiatives/gender-inclusive-initiatives/names-pronouns/update-instructions.html

Prohibition of Recording of Class Sessions by Students

Unauthorized student recording of classroom or other academic activities (including advising sessions or office hours) is prohibited. Unauthorized recording is unethical and may also be a violation of University policy and state law. Students requesting the use of assistive technology as an accommodation should contact AccessibleNU. Unauthorized use of classroom recordings – including distributing or posting them – is also prohibited. Under the University's Copyright Policy, faculty own the copyright to instructional materials – including those resources created specifically for the purposes of instruction, such as syllabi, lectures and lecture notes, and presentations. Students cannot copy, reproduce, display, or distribute these materials. Students who engage in unauthorized recording, unauthorized use of a recording, or unauthorized distribution of instructional materials will be referred to the appropriate University office for follow-up and potential discipline.

Religious Observance

Northwestern is committed to fostering an academic community respectful of and welcoming to persons of differing backgrounds. To that end, the policy on academic accommodations for religious holidays stipulates that students will not be penalized for class absences to observe religious holidays. Students for whom observance of a religious holiday conflicts with a class meeting, exam, or assignment deadline, should consult with their instructor by the end of the second week of the term. Note for undergraduates: if observance of a religious holiday conflicts with a common midterm (i.e., a midterm scheduled outside of the regular class meeting time) or final exam, you should submit an accommodation request to the Office of the Provost's religious accommodation request form.

Support for Wellness and Health

Northwestern University is committed to supporting the wellness of our students. Student Affairs has multiple resources to support student wellness and mental health. If you are feeling distressed or overwhelmed, please reach out for help. Students can access confidential resources through the Counseling and Psychological Services (CAPS), Religious and Spiritual Life (RSL) and the Center for Awareness, Response and Education (CARE). Northwestern also participates in TimelyCare, a virtual mental health platform that provides counseling, health coaching and 24/7 on-demand services at no cost. Additional information on these resources and eligibility can be found here:
https://www.northwestern.edu/counseling/
https://www.northwestern.edu/religious-life/
https://www.northwestern.edu/healthservice-evanston/about-nuhs/who-can-use-nuhs.html
https://www.northwestern.edu/studentaffairs/timelycare.html

Undergraduates In-Person Arrival and Course Engagement

Undergraduate students enrolled in courses with in-person class meetings are expected to be on campus and in attendance no later than the end of the first week of the quarter and must plan to remain until the end of the quarter. Note in some cases, students must attend the first-class meeting to avoid being dropped. This will be clearly identified in CAESAR and the syllabus. Read the full policy:
https://www.northwestern.edu/provost/policies-procedures/classwork-curricular-policies/in-person-arrival.html

The Writing Place
When working on writing assignments for this class, you are encouraged to visit the Writing Place, Northwestern's peer writing center which offers peer consultations for undergraduate and graduate students. A Writing Place consultant can help students at any stage of the writing process. They will not edit your work. Rather, they will work with you to brainstorm ideas, organize or outline an essay, clarify your argument, document your sources correctly, or refine grammar and style. To book an appointment, register for an account at: https://northwestern.mywconline.com

Use of Generative AI Systems

Copilot is the University's supported artificial intelligence service. When using Copilot while actively logged in with a Northwestern account, data is stored securely in Northwestern's Microsoft tenant, and Microsoft will not use it for product improvement or to train its AI models.

Other

A complete list of University policies is available at:
https://www.registrar.northwestern.edu/registration-graduation/northwestern-university-syllabus-standards.html