MACHINE LEARNING & AI (ML)

Departmental Guidelines and Mission Statement

Artificial Intelligence is the science of building machines that exhibit intelligent problem-solving behavior. Machine Learning is an approach within AI whereby machines are trained on datasets to learn their intelligent behavior. Together, these two fields of study have given us new technologies such as the facial recognition algorithm that unlocks our smartphones and the text-generation capabilities of machines like ChatGPT.

Students who pursue the minor in Machine Learning and Artificial Intelligence (MLAI) will gain experience in understanding how these machines work and also how to build them. Students will study the mathematical principles that are critical for making these machines learn in the way they do. Students will explore a variety of important algorithms that form the core of machine learning. Students will have the opportunity to implement these algorithms to solve practical intelligence-requiring problems.

This minor is grounded in the analytical sciences. Students should be adept and comfortable with coding, with moderate to advanced mathematics, and be willing to invest the intellectual time and energy to dive deeply into this realm.

While any Denison student may pursue the MLAI minor, it is designed to most naturally complement a major in computer science, data analytics, or mathematics. There is overlap in the course requirements for those majors and the cognate requirements for this minor, thus facilitating the completion of this minor. Students in a pre-engineering program or physics might also be a good match for the minor.

Faculty

Professor Matt Kretchmar, Program Director

Professors Ashwin Lall (Computer Science), Lew Ludwig (Mathematics), Matt Neal (Mathematics); Associate Professors Anthony Bonifonte (Data Analytics), Emily Marshall (Economics), Fran Lopez-Martin (Modern Language), Regina Martin (English), David White (Mathematics); Assistant Professors Stacey Truex (Computer Science), Adam Waterbury (Mathematics)

Academic Administrative Assistant
Dee Ghiloni

The Machine Learning and Artificial Intelligence (ML) minor positions students to engage, create, and critically evaluate emerging and evolving technologies. Students will learn the fundamentals of machine learning and have the opportunity to explore a variety of techniques, algorithms, and applications. Designed to complement a student's major and broader academic experiences, the minor deepens technical knowledge while reflecting the college's liberal arts mission. With an emphasis on communication, critical analysis, and ethical dimensions, students will approach issues associated with machine learning, artificial intelligence, and algorithms through an integrative perspective.

The following courses are required to complete the minor:

Code	Title
MATH 145	Multivariable Calculus
MATH 213	Linear Algebra and Differential Equations
CS 145	Introduction to Algorithm Design
ML/MATH 221	Applied Probability
ML 222	Applied Probability Seminar
ML/CS 240	Introduction to Machine Learning
ML 310/MATH 428	Intermediate Machine Learning
ML 400	Advanced Machine Learning

Note that MATH 145 has prerequisites of MATH 135 and possibly MATH 130. Students may be placed directly into MATH 145 depending on their prior calculus experience and their score in the math placement exam. Most math majors and a large number of BS CS majors start in MATH 145; it is reasonable to assume most students pursuing this minor will also start in MATH 145. Note also that the most closely aligned majors (MATH, CS, DA) cover many of the cognates in this minor; thus, most students pursuing this minor will need about three to four additional courses beyond what is already required in their major. Similarly, CS 145 requires placement or CS 105 as a prerequisite for CS 145.

Courses

ML 221 - Applied Probability (4 Credit Hours)
This course introduces students to the key conceptual ideas of probability. Students explore these concepts through the use of empirical investigation with data. The course offers substantial programming labs where students increase their algorithmic design and coding proficiency, and also gain familiarity with various Python modules and toolboxes.
Prerequisite(s): MATH 145 and CS 145 or one course from CS 109-CS 114 range.
Crosslisting: MATH 221.

ML 222 - Applied Probability Seminar (1 Credit Hour)
The Applied Probability Seminar complements the pedagogy in the ML 221 Applied Probability course. Students explore the key concepts of probability theory through an empirical investigation methodology. They conduct experiments designed to grow an intuitive level understanding of randomness, distribution, and probability. A key goal of this seminar is to strengthen students' program development skills, introducing key software libraries and design techniques.
Prerequisite(s): ML 221 (coreq) or MATH 221 (coreq).

ML 240 - Introduction to Machine Learning (4 Credit Hours)
An introduction to the fundamental ideas and algorithms of machine learning, emphasizing applications over theory. The course provides early exposure to key concepts and techniques in machine learning.
Prerequisite(s): MATH 145 and CS 105 or CS 145 or one from the CS 109-CS 114 course range or CS 271 or CS 231.
Crosslisting: CS 240.

ML 310 - Intermediate Machine Learning (4 Credit Hours)
This course offers a mathematical treatment of modern machine learning, building on prior exposure to linear models and optimization, emphasizing the analysis and implementation of core algorithms from both a theoretical and practical perspective. Emphasis is placed on connecting mathematical theory with algorithmic implementation and on developing a rigorous understanding of how and why modern machine learning techniques work. Topics include convex optimization, regularization techniques, kernel methods, Bayesian learning, support vector machines, dimensionality reduction, neural networks, and reinforcement learning.
Prerequisite(s): MATH 213 and ML 221 or MATH 221 and ML 222 (coreq).
Crosslisting: MATH 428.

ML 400 - Advanced Machine Learning (4 Credit Hours)
This course is an exploration of the deep learning paradigm that is the foundation of current state-of-the-art AI technology. Students completing this course will understand how the deep learning structure of networks facilitates the learning of advanced concepts. The course introduces the mathematical operations of loss functions and optimization techniques that form the backbone of deep learning architectures. The course then examines two models of deep learning: the convolution neural network used in image processing and the transformer architecture used in large language models.
Prerequisite(s): ML 240 or CS 240 and ML 310 or MATH 428.