DS 340: Introduction to Machine Learning and AI

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Office Hours: MW 3-4:30pm

Course Dates: Jan 18 - May 10
Course Time & Loc: TuTh 2-3:15 EPC 207
Course Credits: 4

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Course Description

This course instructs students in key algorithms for artificial intelligence (AI) and machine learning (ML). This includes depth in the most popular machine learning approach right now, neural networks, as well as breadth in other AI approaches (such as A*) and other ML approaches (such as random forests).

The primary assessment tools will be programming problem sets in Python, using Jupyter notebooks. At the very end of the course, students will present final projects in which they tried a new problem. Each week, they will also submit discussion question responses related to either ethical questions or evaluating grand claims in AI. Their written responses will become fodder for brief discussions in section and class.

Prerequisites

Algorithms (DS320 or equivalent) should be taken simultaneously with or prior to this class. Note that in the DS sequence, this presumes a second semester of programming (DS210) and a completed math sequence that includes probability, linear algebra, and some multivariable calculus (DS120-121-122). If you are coming to this class through a different path, be aware that you will need to learn some of this math, as well as some object-oriented Python.

Learning outcomes

Students will be able to program and reason about a variety of algorithms in AI and Machine Learning, including Monte Carlo Tree Search, Naive Bayes, Decision Trees, Random Forests, Neural Networks, and Q-Learning, in addition to a deep dive into the AI/ML technology of their choosing. Students should also be able to thoughtfully discuss philosophical, ethical, and far-ranging topics in AI.

Instructional Format, Course Pedagogy, and Approach to Learning
The main instructional format will be lectures with occasional questions to the audience. In discussion section, students will discuss philosophical or high-level questions, and also practice the application of AI and ML ideas to code.

A large part of the learning will be in the programming assignments, the discussion questions to answer, and the final project. But a midterm and final exam will also ensure that students are learning about everything the course has to offer, and not just what is tested in these components.

Books and Other Course Materials

Recommended textbook and readings: Russell and Norvig's *Artificial Intelligence: A Modern Approach* (4th edition, ISBN-13 78-0134610993). I will provide optional readings in the syllabus tied to this book, but it won't have required homework problems. It is simultaneously a treasure of a book that makes for a useful reference and source of explanations years after you acquire it; and, not actually that essential to getting a good grade in the course. Seminal papers will be made available on Blackboard.

Recommended hardware: All homework will be run on Google Colab in the cloud, so you actually don't need a powerful machine for this course, as long as it has a Chrome web browser. If you lack a laptop, you can **borrow an acceptable one from BU**. Some compute-intensive projects could require a robust modern machine with a good graphics card to run at an acceptable speed - but if you don't have such a machine, you can just choose from many other project topics.

Courseware

The main course materials will be available on Blackboard, and Q&A will take place on Piazza.

Blackboard: https://learn.bu.edu/

Piazza link: https://piazza.com/bu/spring2024/ds340

Assignments and Grading

The main components of the course grade are:

Assignments	25%
Participation	8%
Midterm	12%
Project	30%
Final exam	25%

The assignments will include both programming and some thought questions. The participation grade requires contributing to discussions (in-class or in section) at least once every two weeks, as well as good faith effort on the weekly exercises in section. The project grade includes the proposal, a final presentation, a final paper, and the working code itself.

The lowest assignment grade that is *not* the ethics assignment will be dropped. If errors on the student's end cause a (non-ethics) assignment to fail to be submitted properly, that is the grade that will be dropped.

The assignments' topics are: Python notebooks about Naive Bayes and Beam Search, Decision Trees and Ensemble Learning, Neural Networks, A* search, Monte Carlo Tree Search; and an ethics essay. All the assignments are weighted equally, even if maximum point values differ.

Resources/Support/How to Succeed in This Course:

1. I recommend coming to office hours (mine or the TA's) if you are stuck on homework, and we will help you get unstuck. (If you are confused about material, the textbook is also very good.) Office hours time is dedicated explicitly to helping you, so don't be afraid to come.
2. If family, health, or other unavoidable circumstances make it impossible to do your work on time, get in touch, and we can probably work something out. I will want a note from a relative or similarly informed person for confirmation.
3. Accommodations for Students with Documented Disabilities: If you are a student with a disability or believe you might have a disability that requires accommodations, please contact the Office for Disability Services (ODS) at (617) 353-3658 or access@bu.edu to coordinate any reasonable accommodation requests. ODS is located at 25 Buick Street on the 3rd floor. Please give me notice of any special needs at least 2 weeks before an exam that requires special accommodations, so that we can schedule space if necessary.

Community of Learning: Class and University Policies

1. I expect everyone to contribute positively to the class environment. Asking questions because you don't understand something, or pointing out something that other students may want to realize, is generally contributing positively. Making a comment that is intended solely to demonstrate that you know more than the rest of the class is not actually contributing positively, unless you take the time to ensure your question or comment can enlighten or interest the rest of the class.

2. **Attendance & Absences.** In general, lecture and recitations will be helpful to you but are not directly required for your grade (besides the participation credit). You are generally encouraged to attend to better prepare you for the exams. In the event of lectures that are de facto mandatory because of exams, I affirm the Policy on Religious Observance.

3. **Assignment Completion & Late Work**. Assignments will be turned in via Blackboard. Students can use up to 5 late days on assignments, no more than 2 per assignment, to turn in work late. Assignments will not be accepted after the late days are used up or after two days. **Discussion questions and project components can't be turned in late.** If you have extenuating circumstances such as health reasons that make it impossible to complete the assignment on time, contact me to apply for an extension or a waived assignment; it will require a note from a parent or other person familiar with your situation.

4. **Academic Conduct Statement.** Collaborations with other students and use of code from the web or ChatGPT-like AIs should always be acknowledged in the assignment or project. **Plagiarism, the reuse of code or text without acknowledgment of the source, is forbidden and punishable with a zero on the assignment and a plagiarism case.** In the case of AI use, students are expected to supply a transcript of the interaction with the AI, as per the CDS GAIA policy (https://www.bu.edu/cds-faculty/culture-community/gaia-policy/). Students can't share or copy each others' code, but they can otherwise collaborate on homework assignments (discussing approaches and solutions) as long as they cite the students they collaborated with in their submission. Some guidelines for what is considered plagiarism in the case of code are here: https://www.bu.edu/cs/undergraduate/undergraduate-life/academic-integrity/. The general academic conduct code is here: https://www.bu.edu/academics/policies/academic-conduct-code/

Hub Learning Outcomes

1. **Quantitative reasoning II** - Students will develop several technical skills, including using search algorithms and employing machine learning. They will even develop skill in probabilistic reasoning itself. These skills will be developed through programming problem sets and the final project. Assignments include a minimax board game player, some sentiment analysis, and reinforcement learning.

1. *Students will frame and solve complex problems using quantitative tools, such as analytical, statistical, or computational methods.*
   The variety of computational tools that students will use to solve include Naive Bayes, Decision Trees, and Q-learning.
2. *Students will apply quantitative tools in diverse settings to answer discipline-specific questions or to engage societal questions and debates.*
   In their final projects, students will have the freedom to apply the techniques they've learned to a variety of domains, including the political if they choose to analyze Tweets and similar data. Students will see a variety of domains through each others' presentations.
3. *Students will formulate, and test an argument by marshaling and analyzing quantitative evidence.*
   Students will argue positions about AI in weekly discussion sections.
4. *Students will communicate quantitative information symbolically, visually, numerically, or verbally.*
   Students will need to communicate about their final projects in their presentations and final papers.

5. *Students will recognize and articulate the capacity and limitations of quantitative methods and the risks of using them improperly.*
   Students will answer response questions in which they evaluate whether AI techniques are being misapplied.

2. **Ethical reasoning -** We will devote one full day to ethical instruction late in the semester, but will also pose ethical discussion questions throughout the semester. Key questions include whether a robot or algorithm designer is responsible for uses of their technology they didn't foresee, and arguing whether it's better to place ethical value on ethical rules or anticipated consequences. Students will be evaluated on their short discussion question responses.
   1. *Students will be able to identify, grapple with, and make a judgment about the ethical questions at stake in at least one major contemporary public debate, and engage in a civil discussion about it with those who hold views different from their own.*
      Students will have a public discussion about whether it's wrong to perform research that advances drone weapon technology.
   2. *Students will demonstrate the skills and vocabulary needed to reflect on the ethical responsibilities that face individuals (or organizations, or societies or governments) as they grapple with issues affecting both the communities to which they belong and those identified as "other." They should consider their responsibilities to future generations of humankind, and to stewardship of the Earth.*
      Students will learn to identify different ethical stances as act consequentialist or rule consequentialist, and will learn about how these two different stances think differently about the far future.

3. **Critical thinking -** Artificial intelligence and machine learning are constantly producing grand claims where the reality is more humble. Discussion questions will ask students to evaluate some of the grander futurist claims while considering the current state of the art. While students won't be required to give up on big claims, the discussion should temper those expectations. To a lesser extent, their experience with the technologies in problem sets and projects may also help them to see the current limitations more clearly. This course also teaches probabilistic reasoning, which is applicable to human reasoning as well.
   1. *Students will be able to identify key elements of critical thinking, such as habits of distinguishing deductive from inductive modes of inference, recognizing common logical fallacies and cognitive biases, translating ordinary language into formal argument, distinguishing empirical claims about matters of fact from normative or evaluative judgments, and recognizing the ways in which emotional responses can affect reasoning processes.*
      Students will learn that the inferences of machine learning are not the same as logical deduction, and will identify ways in which machine learning can be illogical or use "fuzzy" thinking. This will include answering response questions in the homework in which they must explain how machine learning could come to biased or incorrect results, or how it could differ in approach and results from a purely logical approach. Also, first-order logic and probabilistic reasoning will be explicitly taught with associated homework problems.
   2. *Drawing on skills developed in class, students will be able to evaluate the validity of arguments, including their own.*
      Students will evaluate claims made about AI technologies in response questions. If a student is selected for class participation, they may need to defend or elaborate on their position.

Outline of Class Meetings: Date, Topic, Readings, Assignments Due

Schedule of Readings and Due Dates	(R&N is Russell & Norvig 4th edition)
Jan 18	Introduction & history of AI R&N 1.1, 1.3, 2.1, 2.2
Jan 23	Probabilistic reasoning R&N 12.1-12.6
Jan 25	Local search [HW1 out] R&N 4.1-4.2, Ch4 hist notes, 19.6
Jan 30	Intro to ML, Decision trees R&N 19.1-19.3
Feb 1	Ensemble ML [HW1 due, HW 2 out] R&N 19.7-19.8
Feb 6	Abstract ideas in ML R&N 19.4, 19.5, 19.9
Feb 8	Gradient descent and other NN math R&N 19.6.1-19.6.3
Feb 13	Neural networks (NNs) R&N 21.1-21.2
Feb 15	Deep NNs 1 [HW2 due, HW 3 out] R&N 21.3-21.8
Feb 20	Deep NNs 2
Feb 22	NNs over time [FP Proposal out] R&N 21.6
Feb 27	NNs and language [HW3 due] R&N Ch 24
Feb 29	Utility & MDPs [FP Proposal due] R&N 16.1-16.3, 17.1-17.4, 17.6
Mar 5	MIDTERM
Mar 7	Reinforcement learning [HW 4 out] R&N 22.1-22.3
Mar 11-15	SPRING BREAK
Mar 19	RL cont'd, deep Q R&N 22.4, Mnih et al 2013
Mar 21	GOFAI: Logic etc [HW4 due, HW 5 out] R&N 3.1-3.6
Mar 26	Minimax R&N 5.1-5.3
Mar 28	MCTS [HW5 in, HW 6 out] R&N 5.4-5.5
Apr 2	Graphical models R&N 13.1-13.4
Apr 4	Ethics of AI [HW 6 in, Ethics out]
Apr 9	Unsupervised learning & EM R&N 20.3

Apr 11	Recommender Systems [Ethics in] https://tinyurl.com/4m9cymmn
Apr 16	Autoencoders & GANs
Apr 18	Diffusion models and AI Art
Apr 23	Philosophy of AI, Conclusions R&N 27.1-3
Apr 25	Final project lightning talks 1
Apr 30	Final project lightning talks 2
May 6-10	FINAL EXAM

~last modified 1/19/24~