DS 340: Introduction to Machine Learning and AI

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Course Dates: Sep 5 - Dec 12
Course Time & Loc: TuTh 12:30-1:45 EPC 207
Course Credits: 4

Course Description

This course instructs students in key algorithms for artificial intelligence (AI) and machine learning (ML). Along the way, we seek to explore what kinds of problems these techniques are good and bad at.

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

A second course in programming (DS210 or equivalent) should be taken prior to this class, and algorithms (DS320 or equivalent) should be taken simultaneously with or prior to this class.

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 additionally discuss philosophical or high-level questions that have been posed previously online. In discussion section, they will further do exercises that help clarify the concepts currently being taught in class.

A large part of the learning will be in the programming assignments, the discussion questions to answer, and the final project.

Books and Other Course Materials

Recommended textbook and readings: Russell and Norvig's *Artificial Intelligence: A Modern Approach* (4th edition). 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 (especially GANs, a kind of neural network) 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.

Piazza link: https://piazza.com/bu/fall2023/ds340

Assignments and Grading

The main components of the course grade are:

Assignments	50%
Discussion section participation	10%
Project	40%

The assignments will include both programming and some thought questions. The discussion section participation requires contributing to at least 1 out of every 2 consecutive discussions in section, on topics to be announced in-section, as well as attendance of all discussion sections. The project grade includes the proposal, a final presentation, a final paper, and the working code itself.

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.) Do not worry about wasting our time - office hours time is dedicated explicitly to helping you.
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.

Community of Learning: Class and University Policies

1. I expect everyone to contribute positively to class contributions. Please speak if you haven't spoken in a while, and please let others speak if you've said a few things. Be kind to other students. Do not be doing something on your screen that could distract other students.

2. **Attendance & Absences.** In general, lecture will be helpful to you but is not required for your grade. You can judge for yourself whether you should attend, though I expect you generally should. Recitation, on the other hand, is graded. You can waive a recitation grade if you are ill or have an unavoidable commitment. 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.

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 that becomes a part of your permanent record.** 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. *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)
Sep 5	Introduction & history of AI R&N 1.1, 1.3, 2.1, 2.2
Sep 7	GOFAI: A*, Logic, Planning [HW1 out] R&N 3.1-3.6
Sep 12	Local search: hill climbing, GAs, etc. R&N 4.1-4.2, Ch4 hist notes, 19.6
Sep 14	Adversarial search R&N 5.1-5.3
Sep 18 (Mon)	*HW 1 due*
Sep 19	Monte Carlo Tree Search [HW2 out] R&N 5.4-5.5
Sep 21	Probabilistic reasoning R&N 12.1-12.6
Sep 25 (Mon)	*HW2 due*
Sep 26	Graphical models [HW3 out] R&N 13.1-13.4
Sep 28	Intro to ML, Decision trees R&N 19.1-19.3
Oct 2 (Mon)	*HW3 due*
Oct 3	Ensemble ML [HW4 out] R&N 19.7-19.8
Oct 5	Abstract ideas in ML R&N 19.4, 19.5, 19.9
Oct 10	MONDAY SCHEDULE - NO CLASS
Oct 11 (*Wed)*	*HW4 due*
Oct 12	Neural networks [FP proposals out] R&N 21.1-21.2
Oct 17	Deep neural networks R&N 21.3-21.8
Oct 19	Using Keras [HW5 out]
Oct 24	Neural networks over time R&N 21.6
Oct 25 (Wed)	*FP Proposals Due*
Oct 26	Utility & MDPs R&N 16.1-16.3, 17.1-17.4, 17.6
Oct 31	Reinforcement learning R&N 22.1-22.3
Nov 1 (Wed)	*HW5 due*
Nov 2	RL cont'd, deep Q [HW6 out] R&N 22.4, Mnih et al 2013

Nov 7	Unsupervised learning & EM R&N 20.3
Nov 9	Recommender Systems https://tinyurl.com/4m9cymmn
Nov 13 (Mon)	*HW6 due*
Nov 14	Ethics of AI [Ethics assign out]
Nov 16	Natural Language R&N Ch 23
Nov 20 (Mon)	*Ethics assignment due*
Nov 21	More NLP: embeddings R&N Ch 24 *Project check-in by today*
Nov 22-26	THANKSGIVING - NO CLASS
Nov 28	Autoencoders & GANs
Nov 30	Diffusion models and AI Art
Dec 5	Philosophy of AI, Conclusions R&N 27.1-3
Dec 7	Final project lightning talks 1
Dec 11 (Mon)	*Final project code and paper due*
Dec 12	Final project lightning talks 2

~last modified 8/31/23~