Introduction to Artificial Intelligence
CS 5260, Spring 2023

Will Hedgecock

Motivation

Artificial Intelligence (AI) is being discussed in the public sphere as never before. While AI has always been a popular topic of science fiction, high-profile technologists are now actively contemplating the potential dangers of AI, particularly the prospect of **general (or autonomous or strong) AI** and the subsequent displacement of the human species as the dominant entities on our planet. In contrast, optimistic views of general AI focus on the potential of AIs as companions, caregivers, and advisers in a wide range of areas. In the realm of general artificial intelligence, the optimistic view is also that general **AIs can be positive role models to humans** and that **collective intelligence** composed of both humans and AIs will be more powerful and compassionate than either "species" would be alone.

While this course considers today's nascent steps toward general AI in the form of AI **agents** that integrate various functionalities at a systems level, such as home assistants and autonomous vehicles, we also consider the tool-based perspective of AI, where we study the nuts-and-bolts concepts and algorithms used by **task-specific (or narrow or weak) AIs**. We will study the declarative encoding of knowledge in a computer and the procedural reasoning that the computer performs with that knowledge and observations from the environment. While AIs that support very specific tasks may seem less exciting than general AIs, it is these task-specific AIs that are driving much public debate: for example, about using machine learning to automate recommendations for prisoner parole and job-candidate interviews and about the use of computer vision and image processing for facial recognition in retail and law enforcement. On the other hand, task-specific AI may be used to strengthen human decision-making in areas such as environmental sustainability, resource management, health care, and education.

Course Coverage

In this introductory course, students will learn the concepts and methods of core AI areas, including search and exploration, knowledge representation, inference and planning, reasoning with and without various forms of uncertainty, and machine learning. In one semester we will not touch on all broad areas of AI, but in addition to mastering what we do study, my expectation is that students will be better prepared and informed for advancing in AI, be it from formal coursework or from independent study.

Asynchronous Material

Prerecorded video lectures on Brightspace are the most important source of information for this class, but the textbooks listed below should also be used for further understanding as needed. The video lectures, which sum to approximately 75 minutes per week, are important to watch before you attempt the corresponding week's homework. Most of the lectures through week 10 contain self-recorded information on the fundamentals of AI, with publicly available guest lectures dominating the latter half of the semester on special topics.

Textbooks

The two required textbooks for this course are:

- **Russell, S. J., & Norvig, P. (2021). *Artificial intelligence: A modern approach* (4th ed.). Pearson Education, Inc.** This book has the advantage of including material that goes well beyond what we can expect to do in one semester, covering areas such as vision and robotics, thus supplying ample material for continued study. Russell & Norvig **(RN)** is available in various modalities. Information is available at http://aima.cs.berkeley.edu.
- **Poole, D. L., & Mackworth, A. K. (2017). *Artificial intelligence: Foundations of computational agents* (2nd ed.). Cambridge University Press.** This book is closer to what one would hope to cover in a one-semester course but includes additional material. Poole & Mackworth **(PM)** is available in hard copy and free online at https://artint.info.

Both textbooks were written by top-tier AI researchers, and the course lectures draw on publicly available auxiliary material (e.g., slides, exercises) from the websites of both books. Each week, the **Schedule** below identifies the textbook material in both RN and PM that is relevant to the week's video lectures.

Additionally, there are other textbooks that can be good resources. Some are out-of-print and online:

- Winston, P. H. (1992). *Artificial intelligence* (3rd ed.). Pearson Education, Inc. Out of print. This classic text is now available at https://courses.csail.mit.edu/6.034f/ai3/rest.pdf. Winston arguably wrote the first AI textbook in the mid-1970s, from which this third edition grew. His Third edition has 10 chapters on various styles of machine learning.

Another text on the history of AI by one of the founders may interest some:

- Nilsson, N. (2009). *The quest for artificial intelligence: A history of ideas and achievements*. Cambridge University Press. This book is available from Cambridge University Press, and a free online web version is available at: http://ai.stanford.edu/~nilsson/QAI/qai.pdf.

Discussion Forum

A Discussion Forum exists for students to ask questions and give comments on any aspect of the course. The instructor will respond as appropriate, but students are encouraged to respond too. I also encourage knowledge sharing of ideas, specifications, and designs regarding the programming projects and knowledge checks (but NOT the homework assignments). In general, students can and should be learning from other students in this course. There may also be prompts from me for questions and comments regarding the readings, the asynchronous lectures, the practice problems, the programming project, and issues of current relevance. Also, if you find an interesting paper or topic, feel free to post that as well.

We will be using Piazza as the Discussion Forum for this class. If you have not been previously enrolled by the instructor, you can join the class forum after class convenes at https://piazza.com/vanderbilt/spring2023/cs5260 using Access Code `cs5260ai`.

Synchronous Live Sessions

A live class session of 75 minutes will occur each week on Wednesdays from 5:00 PM to 6:15 PM US Central Time on Zoom (https://vanderbilt.zoom.us/j/94185981738?pwd=SjNCZjhYZUlpMjVrRFJNSnFENlY2Zz09). Each live session opens with a 15- to 20-minute lecture on material relevant to the week's theme, a 10- to 15-minute discussion of the programming project, a 5-minute stretch, and Q&A for the remainder of the session. Issues that arose on the Discussion Forum that week will also be discussed in the last segment.

Homework

There is typically a weekly *required* homework. There are two aspects to each homework assignment:

1. You are given questions that ask for open-format answers (e.g., show a proof for X). You will turn in a PDF of your open-format answers to Brightspace under Assignments.
2. For grading purposes, you will take a "quiz" on exactly those questions for which you uploaded answers. You can take the quiz component on Brightspace (under Quizzes) as many times as you like, but the overall grade that you receive for each assignment will be based on the following formula: ((% correct on 1^{st} try) + (2 * (% correct on last try))) / 3

I may use your free-form answers from Item 1 to check your work, particularly if you do poorly on the quiz component, and I may adjust the homework score accordingly. Thus, think of the free-form answer as "showing your work" for the quiz version that will actually count as your grade.

Having watched and understood the weekly lecture videos will typically be enough to answer most homework problems, but in some cases, you will have to look for answers elsewhere, typically in a textbook.

Knowledge Checks

Optional ***Knowledge Checks*** are practice problems, which are typically drawn from the online exercises and resources of the textbooks above. You can work with others on Knowledge Check problems, and you can post and discuss your solutions to the Discussion Forum.

Final Exam

There will be a single, comprehensive final exam taken near the end of the term.

Programming Project

A semester-long, required programming project will be assigned in the first couple of weeks of class and broken into two deliverables, Part 1 and Part 2. You can use the programming language of your choice for this project; however, you will be submitting a program listing that should be well-documented. You will also submit a video in which you illustrate technical details and experimental studies of your code, which may be above and beyond the requirements of the assignment. You can optionally post these videos to the Discussion Forum for all students to see and comment on.

Programming Project Parts 1 and 2 are tentatively due in Weeks 9 and 14.

The programming project is intended to promote individual creativity but also community knowledge sharing. You are encouraged to share ideas and designs on the Discussion Forum but not to share code unless approved by me. An important rule of thumb is that if you share something with anyone, then you share with everyone. Another important rule is to cite the sources of your ideas and designs, most notably those of other students.

Programming deliverables are to be uploaded to Brightspace and will be graded along the following factors:

- 50% execution correctness, including selection of test cases and instrumentation
- 20% structure (e.g., modularization, information hiding, etc.)
- 20% video presentation of your results
- 10% appropriate commenting style

Community Score

A **community score** will be computed from the number of citations you receive from others who have adopted/adapted your intellectual contributions and, to a lesser extent, when you adopt/adapt (and cite) the contributions of others. Other aspects of the community score are your engagement in the Discussion Forum and the Live Sessions. Your community score can contribute up to 2% extra credit on your total grade.

Grading

- Homeworks: 60%
- Programming Project: 30%
- Final Exam: 10%
- Community Score: Up to 2% extra credit

There is no "curve" and thus no disincentive for knowledge sharing over the Discussion Forum in a manner consistent with the Honor Code. The letter grade breakdown for a score of x is:

- $92 \leq x \leq 100$ A
- $90 \leq x < 92$ A-
- $87 \leq x < 90$ B+
- $82 \leq x < 87$ B
- $80 \leq x < 82$ B-
- $77 \leq x < 80$ C+
- $72 \leq x < 77$ C
- $70 \leq x < 72$ C-
- $67 \leq x < 70$ D+
- $62 \leq x < 67$ D
- $60 \leq x < 62$ D-
- $0 \leq x < 60$ F

I do not round up. For example, an 86.9 is a B, not a B+.

Honor Code

Exams are **closed everything** except your own brain – all work is to be your own. You are otherwise free to discuss knowledge check practice problems and other course material with other students and to post on the Discussion Forum. You can consult the textbooks and videos while doing all homework assignments; however, you cannot consult with other students on the answers. Any clarification questions should be posted to the Discussion Forum.

Regarding programming projects, your interactions with other students is more open, even loosely collaborative. You can share information and insights, even possible posting of code, subject to restrictions on the timing and size of these posts, and by permission from me only. **You can interact with other students only "in the open" — that is, in live sessions and on the Discussion Forum. If you want to share with another student, then you must share with all students.** If you adopt and adapt the insights of another student or anyone else, then you must acknowledge that usage in all applicable deliverables. These acknowledgments will contribute to your community score and to the community score of the other students.

Schedule

Relevant readings from the Russell & Norvig (RN) and Poole & Mackworth (PM) textbooks are given for each week. Out of respect for your time, I encourage the following weekly study strategy: (1) look at the homework assignment for that week to know the questions that you will need to answer, (2) read the required textbook material, (3) lightly scan any additional reading material you feel you need for further clarification, (4) watch the videos, (5) do the homework, both open-format and quiz, consulting the texts and videos as necessary. You will also have to allot time for the Programming Project.

Week 1 | AI Overview

- Readings:
  - RN: Chapters 1 and 2 (*required*)
  - PM: Chapters 1 and 2 (*optional*)
- Video Lectures:
  - What is Artificial Intelligence?
  - Why Study Artificial Intelligence?
  - Thinking about Thinking
  - Tools, Agents, and Environments

Week 2 | Exploring Alternatives with Search

- Readings:
  - RN: Chapter 3 (*required*)
  - PM: Chapter 3 (*optional*)
- Video Lectures:
  - Uninformed Search of an Explicit Graph without Costs
  - Depth-First Search of an Explicit Graph without Costs
  - Uninformed Search with Checks for Repeated Vertices
  - Breadth-First Search with Checks for Repeated Vertices
  - Uninformed Search of an Explicit Graph with Costs
  - Embedding Path Information in State Descriptions
  - Informed (or Heuristic) Search of an Explicit Graph
  - Greedy Best-First Search of an Explicit Graph
  - Heuristic Depth-First Search of an Explicit Graph
  - A* Search of an Explicit Graph
  - Searching an Implicit Graph
  - Searching an Implicit Graph: A World Trade Game
  - The Generic Algorithm for Searching Implicit Graphs

Week 3 | Additional Search Paradigms

- Readings:
  - RN: Chapter 4 intro; 4.1; 4.3; 4.4; intro paragraph of 4.5 (*required*)
  - RN: Chapter 5 through 5.3 (*required*)
  - RN: Chapter 6 through 6.4 (*required*)
  - RN: Other Chapter 4, 5, or 6 sections (*optional*)
  - PM: Chapter 4 through 4.4 (*required*)
  - PM: Chapter 11 through 11.3 (*optional*)
- Video Lectures:
  - Variants of the Generic Algorithm
  - Search with Macro Operators
  - Adversarial Search in Games
  - More Efficient Game Search
  - Constraint-Based Reasoning through Search
  - Generalized Arc Consistency

Week 4 | Project Part 1 Kickoff

- Introduction to the Programming Project
- Catch-up and internalize material from Weeks 1-3

Week 5 | Inference with Propositional Logic

- Readings:
  - RN: Chapter 7 (*required*)
  - PM: Chapter 5 (*optional*)
- Video Lectures:
  - Backward Inference
  - Searching for a Proof
  - Forward Inference
  - Embedding Inference in an Agent
  - Theorem Proving with Resolution
  - Searching for Resolution Proofs
  - Propositional Planning

Week 6 | Reasoning with Uncertainty

- Readings:
  - RN: Chapter 12 through 12.5 (*required*)
  - RN: Chapter 13 excluding 13.2.2, 13.2.3, and 13.4 (*required*)
  - RN: Remainder of Chapter 12 (*optional*)

- RN: Remainder of Chapter 13 (*optional*)
- PM: Chapter 8 through 8.3 (*optional*)

- Video Lectures:
  - Probability Basics
  - Conditional Probability
  - Bayes Rule
  - The Chain Rule
  - Statistical Independence
  - Building a Bayesian Network
  - Knowledge of Conditional Independencies
  - Computing Full Joint Probabilities
  - Computing Partial Joint Probabilities
  - Computing Conditional Probabilities

Week 7 | Bayesian Networks and Naive Bayesian Classifiers

- Readings: Continue with readings from Week 6
- Video Lectures: Continue with video lectures from Week 6

Week 8 | Sequential Inference and Learning from Examples

- Readings:
  - RN: Chapter 14 through 14.3; 14.5 through 14.5.2 (*required*)
  - RN: Chapter 19 through 19.4 (*required*)
  - RN: Remainder of Chapter 19 (*optional*)
  - PM: Chapter 7 through 7.4 (*optional*)
  - PM: Chapter 8.5 (*required*)

- Video Lectures:
  - Markov Models
  - Hidden Markov Models
  - Decision Trees
  - Learning Decision Trees
  - Decision-Tree Learning as Search
  - Properties of Decision Trees
  - Model Selection and Evaluation

Week 9 | Decision Making

- Readings:
  - RN: Chapter 5.5 (*required*)
  - RN: Chapter 16 through 16.5 (*required*)

- RN: Chapter 17 through 17.2 (*required*)
- RN: Chapter 18.4 (*required*)
- RN: Other Chapter 16 and 17 sections (*optional*)
- PM: Chapter 9 through 9.2 (*required*)
- PM: Chapter 9.5 (*optional*)
- PM: Chapter 11.4 (*optional*)

- Video Lectures:
  - Probabilistic Game Search
  - Expected Utility
  - Markov Decision Processes
  - Expectimax Search for Finding Best Actions
  - Best Policies
  - Value Iteration

Week 10 | Project Part 1 Delivery, Part 2 Kickoff

- Finalize Programming Project Part 1 (including the video)
- **Submit Project Part 1. Submission window opens after Live Session 10 and closes March 15 at 11:59PM CST.**

Week 11 | First-Order Logic

- Readings:
  - RN: Chapter 8 (*required*)
  - RN: Chapter 10 through 10.1; 10.5 through 10.5.1 (*required*)
  - RN: Remainder of Chapter 10 (*optional*)
  - PM: Chapter 13 through 13.5 (*optional*)
  - Winston's book has material on knowledge representation that is helpful (Chapters 2 and 13), but strictly optional

- Video Lectures:
  - Basics of First-Order Logic Representations
  - Unification and Inference
  - Backward Inference

Week 12 | Probabilistic Relational Models

- Readings:
  - RN: Chapter 9 through 9.3.2; 9.4 through 9.4.2; 9.5 (*required*)
  - RN: Chapter 11 through 11.2.2 (*required*)
  - RN: Chapter 15 (*optional*)
  - PM: Chapter 15 through 15.3 (*optional*)

    - Winston's book has material that is helpful (Chapter 15), but strictly optional
- Video Lectures:
    - First-Order Resolution Theorem Proving
    - Planning with First-Order Representations
    - Relational Learning

Week 13 | Ethics and the Future of AI

- Readings:
    - RN: Chapters 27 and 28 (*required*)
    - PM: Chapter 16 (*optional*)
- Video Lectures:
    - Montage by Guest Interviewees
- **Final Exam: Submission window opens after Live Session 13 and closes on Sunday at 11:59PM CST (roughly 100 hours later). The time for the exam is limited to 75 minutes.**

Week 14 | Project Part 2 Delivery and Wrap-Up

- **Submit Project Part 2. Submission window opens after Live Session 14 and is due by 11:59 PM US Central Time on the last day of classes.**