CS 540, Section 2

Introduction to Artificial Intelligence

Chuck Dyer
Spring 2017

The Waiting List

• This class (and the other section of CS 540) is currently completely full

• If you are enrolled but decide to drop, please do so ASAP

• I will admit a few students from the waiting list as students drop, but priority will be given to undergrad CS majors who are close to graduation, and who sign in each class during the first 2 weeks

Course Information

http://pages.cs.wisc.edu/~dyer/cs540.html

• Textbook:


• Powerpoint slides
• Piazza for Q & A (you cannot be anonymous to instructor)
• Moodle for homework electronic hand-in

Instructor

Chuck Dyer

• Chuck, Prof. Dyer, Dr. Dyer
• Ph.D., University of Maryland
• M.S., UCLA
• B.S., Stanford
• Hometown: San Diego
• Research: Computer vision
• Fun: Running (PRs: 4:22 mile, 2:41 marathon)
• Office Hours: MW 2-3 p.m.
Teaching Assistants

Tuan Dinh
Office Hours: RF 4-5

Dan Griffin
Office Hours: MT 4-5

Teaching Assistants

Rashi Jalan
Office Hours: MW 11-12

Xiaomin Zhang
Office Hours: TR 11-12

Prerequisites

• Basic JAVA programming (CS 302)
• Data structures (CS 367)
• Curiosity, enthusiasm and dedication

• Other Helpful Topics (though not prereqs)
  • Calculus (e.g., Math 221)
  • Discrete Math (CS/Math 240)
  • Probability and statistics (e.g., Stat 324)
  • Linear algebra (e.g., Math 340)
  • Logic

Workload

• 5 homework assignments (40% of grade)
  • A programming problem and written problems
  • Due time: 11:59 p.m. on due date
  • Late penalties:
    • 1 day: 10% off
    • 2 days: 25% off
    • 3 days: 50% off
    • 4 or more days: 100% off
    • 3 “free late days”

• 2 examinations (each 30% of grade)
  • Midterm: Thursday, March 9, 7:15 – 9:15 p.m.
  • Final: Sunday, May 7, 5:05 – 7:05 p.m.
Things to Do

- Look at the course web page:
  - pages.cs.wisc.edu/~dyer/cs540
- Activate your CS instructional Linux workstation account
  - If you had an account in the fall, you do **not** need to re-activate your account; use same CS login
  - Otherwise, go to https://csl.cs.wisc.edu and click “Activate Account”
- Sign up on Piazza
  - https://piazza.com/wisc/spring2017/cs540section2/home
- Review Java (and, if desired, Eclipse IDE)
- Skim Chapters 1 and 2 (focusing on 1.1, 2.1, 2.2, 2.3), and read 3.1 – 3.4

CS 540 Main Topics

- Problem solving as Search
  - Heuristic search algorithms, game playing, …
- Machine learning (inductive inference)
  - Unsupervised and supervised learning
- Probabilistic reasoning
- Deductive inference using logic as a representation language
- Applications
  - Speech recognition
  - Computer vision
  - Natural language processing
  - Robotics

Sample 540 Programming Projects

- Map route finding
- Puzzle solving
- Game playing: Checkers, Backgammon, Othello
- Face detection and recognition from images
- Character recognition from images
- E-mail spam detection
- Breast cancer diagnosis
- Semantic spell correction (e.g., two vs. to vs. too)
- Movie rating system using sentiment analysis of text to extract subjective information such as “likes” or “dislikes”

Course Syllabus (approximate)

- Problem solving as search (4 weeks)
- Machine learning (4 weeks)
- Probabilistic reasoning (3 weeks)
- Speech recognition (1 week)
- Computer vision (1 week)
- Representation and inference using logic (1 week)
What is AI?

- “AI is the study of complex information processing problems that often have their roots in some aspect of biological information processing. The goal of the subject is to identify solvable and interesting information processing problems, and solve them.”
  – David Marr

- The intelligent connection of perception to action
  – Rodney Brooks

- Actions that are indistinguishable from a human’s
  – Alan Turing

The Turing Test

- Can machines think? → Can we tell if a conversation is by a machine and not a human?
- Text in, text out
- Operational test for intelligent behavior: aka the Imitation Game

- Predicted that by 2000, a machine might have a 30% chance of fooling a lay person for 5 minutes
- Suggested major components of AI: knowledge rep., reasoning, natural language processing, learning

“My personal challenge for 2016 is to build a simple AI to run my home and help me with my work. You can think of it kind of like Jarvis in Iron Man. I’ll start teaching it to understand my voice to control everything in our home ... I’ll teach it to let friends in by looking at their faces when they ring the doorbell ... I’ll teach it to let me know if anything is going on in Max’s room that I need to check on ...”

– Mark Zuckerberg, Facebook

Different Approaches to AI

- Philosophy, ethics, religion
  ▪ What is intelligence?

- Cognitive science, neuroscience, psychology, linguistics
  ▪ Understand natural forms of intelligence
  ▪ Learn principles of intelligent behavior

- Engineering
  ▪ Can we build intelligent devices and systems?
  ▪ Autonomous and semi-autonomous systems for replicating human capabilities, enhancing human capabilities, improving performance, etc.
Some Successful AI Applications

1. Language translation services (Google)
2. Translating Telephone (Skype)
3. News aggregation and summarization (Google)
4. Speech recognition (Nuance)
5. Song recognition (Shazam)
6. Face recognition (Recognizr, Google, …)
7. Image recognition (Google)
8. Question answering (Apple Siri, IBM Watson, …)
9. Chess playing (IBM Deep Blue)
10. 3D scene modeling from images (Microsoft Photosynth)
11. Driverless cars (Google)
12. Traffic prediction system (Inrix)

AI is Hard

• AI problems often involve large, complex data
  ▪ Speech, images, natural languages, genomic data, …
  ▪ What are the right primitives to use?
  ▪ Data are often noisy, unstructured and have missing values
• Computationally (NP-) hard
• Very hard to define general, computational “competence theories” for specific tasks that say what is computed and why (what to compute)
• Need algorithms that use domain-specific knowledge and constraints with incomplete models, while being time and space constrained, stable, and robust (how to compute)

Some Challenging AI Task Characteristics

• Is the environment fully observable or partially observable?
• An environment is fully observable if we have access to the complete state of the environment at any point in time
• If all aspects that are relevant to the choice of action are able to be detected, then the environment is effectively fully observable
• Note: Noisy, incomplete and inaccurate sensors can result in partially observable environments

AI Task Characteristics

• Is the task deterministic or stochastic?
• A problem is deterministic if the next state of the world is completely determined by the current state and the agent’s actions
• Randomness and chance are common causes of stochastic environments
### Al Task Characteristics

- **Is the task episodic or sequential?**

  - An environment is **episodic** if each percept-action step does *not* depend on the actions in prior steps; *independence of action decisions*

  - Games are often **sequential** requiring one to think ahead; solution is a sequence of steps

- **Is the data/environment static or dynamic?**

  - An environment is **static** if it doesn't change between the time of perceiving and acting

  - An environment is **semi-dynamic** if it doesn't change but the agent does

  - Time is an important factor in dynamic environments since perceptions can become "stale"

- **Is the task discrete or continuous?**

  - A problem is **discrete** if there are a bounded number of distinct, clearly-defined states of the world, which limits the range of possible percepts and actions

- **Is the problem single agent or multi-agent?**

  - An environment is **multi-agent** if more than one agent (computer or human) can affect the other's performance

  - Multi-agent environments can be competitive ("adversarial") or not ("benign")
**AI Paradigm**

- Develop general, efficient, satisficing (i.e., acceptably good) methods for tackling AI problems
- Given a real-world task,
  1. Convert it into a form that is well-defined and captures all relevant information necessary to solve it – this is a “modeling” process
    - Example: Model the “relevance” of a web page, \( x \), to a user’s search query as:
      \[ f(x) = 10 \times \text{QueryMatch}(x) + 3 \times \text{PageRank}(x) \]
  2. Given a formal model, develop an algorithm for solving the task efficiently

**AI Today**

- A set of “tools” for computing a variety of useful classes of model types that represent information extracted from raw input data, and use associated algorithms to “solve” specific tasks
  - Neural networks, hidden Markov models, Bayesian networks, heuristic search, logic, …
  - There’s no magic in AI. It’s all about models (i.e., representation), probability, statistics, optimization, and algorithms

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**Models To Be Studied in CS 540**

- **State-based Models** (Search, Planning)
  - Solutions are defined as a sequence of steps
  - Model task as a graph of states and solution as a path
  - A state captures all the relevant information about the past in order to act (optimally) in the future
  - Apps: navigation, games
  - State-space graphs
- **Parametric, Reflex Models** (Machine Learning)
  - Given a set of (input, output) pairs of training data, learn a set of parameters that will map input to output for future data
  - Apps: classification, regression
  - Decision trees, neural networks, SVMs, k-NN

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**Models to be Studied in CS 540**

- **Variable-based Models** (Uncertainty)
  - Solution is an assignment of values for a set of variables
  - Apps: Sudoku, speech recognition, face recognition
  - Constraint satisfaction, Bayesian networks, Hidden Markov Models, CNNs
- **Logic-based Models** (Logic)
  - Symbolic representation of classes of objects
  - Deductive reasoning
  - Apps: Question answering systems, natural language understanding
  - Propositional logic, First-order logic
Some AI Applications

A.L.I.C.E. Chatbot

Jerry: My name is jerry.
ALICE: Hey jerry.
Jerry: Do you know Turing?
ALICE: A brilliant and tragic figure in the history of computer science.
Jerry: Who else do you know?
ALICE: Hugh Loebner, Robby Garner, and Steven Spielberg
Jerry: Which film do you like?
ALICE: My favorite movie is Teknolust. Have you seen it?
Jerry: No.
ALICE: I would recommend you check it out.
Jerry: What is it about?
ALICE: Science fiction.
Jerry: Do you remember my name?
ALICE: Your name is Jerry, seeker.

Natural Language Understanding:
Chatbots

ALICE: 2004 Loebner Prize winner
ELIZA: psychotherapist
Valerie: CMU Robot Receptionist

Natural language processing, pattern matching

Valerie Loebner Prize, awarded annually to best AI program

Speech Recognition

- “speak or touch tone your card number” (tiny vocabulary, high accuracy needed)
- call routing, airline reservations: “how can I help you?” (large vocab, low accuracy)
- dictation (large vocab, high accuracy)

IBM ViaVoice
Nuance Dragon NaturallySpeaking

- Hidden Markov Models, heuristic search, …
The spirit is willing but the flesh is weak.  [Bible, Matthew 26:41]

- Statistical machine translation models
  translate.google.com

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**Machine Translation**

**Question Answering Systems**

**Apple Siri**

Speech recognition and language understanding

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**Question Answering**

- IBM Watson
- Jeopardy! game player in January 2011
  - 4 TB of data analyzed
- Now used as a clinical decision support system, e.g., for lung cancer treatment

- Shallow natural language processing, heuristics
Game Playing: Chess

- IBM Deep Blue vs. Kasparov, 1996
- 6 games: K, D, draw, draw, draw, D
- IBM stock up $18 billion

- Search: two-player zero-sum discrete finite games with perfect information

Game Playing: Go

Google AlphaGo beat Korean grandmaster Lee Sedol 4 games to 1 in 2016

Web Page Ranking

- Google PageRank uses Machine Learning

News Aggregation and Summarization

- Automatically selects, summarizes, and arranges news from multiple sources
  - [http://news.google.com](http://news.google.com)

- Unsupervised machine learning: clustering
Web Advertising

- “Sponsored links”
- Show ads based on relevance and money
- Online algorithm, game, auction, multiple agents

Navigation

- Google Maps, Bing Maps, MapQuest
- FedEx, UPS to plan package delivery
- Search

Web Information Extraction

- Extract job info, free web text → DB
- UW HAZY project: Extracts information from natural language text for knowledge base construction
- Machine learning: classification

Collaborative Filtering

- Recommendations based on other users’ behavior
- e.g. Amazon
- e.g. Netflix
- Unsupervised learning
Netflix Prize

$1 million prize awarded in 2009; training set included 100 million ratings for 480,000 users and 18,000 movies

Visual Search: Google Goggles

Face Detection in cameras for auto focusing

Also blink and smile detection!

Face Recognition: Autotagging Photos in Facebook, Flickr, Picasa, iPhoto, …
Handwriting Recognition

- When you deposit a check at an ATM, handwriting recognition automatically “reads” the amount
- When you mail a letter, the USPS automatically reads the address and zip code

Body Part Detection and Tracking

Autonomous Robots

- Key questions in mobile robotics
  - What is around me?
  - Where am I?
  - Where am I going?
  - How do I get there?
- Alternatively, these questions correspond to
  - Sensor Interpretation: what objects are in the vicinity?
  - Position and Localization: find your own position on a map (given or built autonomously) and position on road
  - Map building: how to integrate sensor information and your own movement?
  - Path planning: decide the actions to perform for reaching a target position

Space Exploration Robots

Driving on Mars by Sojourner, Spirit, Opportunity, and Curiosity rovers
Cleaning Robots

• iRobot Roomba robot for vacuuming floors

Lawn Mowing Robots

Robomow

Physical Assistants: Robots to Help the Elderly and Impaired

Robots Playing Soccer
Driverless Vehicles
Cars, airplanes, helicopters, birds, insects

What’s Needed?
- Car Information
  - Position and orientation of car, velocity and turning rate of car
- Environment Information
  - Where is the road, curb, road signs, stop signs, other vehicles, pedestrians, bicyclists, …
- Actions
  - Velocity, steering direction, braking, …
- Sensors
  - Video cameras, radar, LIDAR, GPS, …

Driverless Car Task Characteristics
- Fully or partially observable?
  - Partially observable
- Deterministic or stochastic?
  - Stochastic
- Static or dynamic?
  - Dynamic
- Discrete or continuous?
  - Continuous
- Single or multi-agent?
  - Multi-agent
Driverless Cars

DARPA Grand Challenges

- DARPA Grand Challenge I
  - Barstow to Primm
  - March 13, 2004
  - 142 miles
  - 10 hours

- DARPA Grand Challenge II
  - Desert Classic
  - October 8, 2005
  - 132 miles
  - 10 hours

- DARPA Grand Challenge III
  - Urban Challenge
  - November 3, 2007
  - 60 miles
  - 6 hours

The 2005 “Grand Challenge” Race

The 2007 “Urban Challenge”

- Driving in urban environments
- Obey all traffic laws
- Accommodate road blockages, other vehicles, etc.

Google’s Driverless Car

Video camera on windshield detects traffic lights and moving traffic

Rotating sensor on roof generates 3D map of surroundings

Radar sensors - three at the front and one at the back - help determine position

Two people in car - driver to take over in an emergency, and engineer to monitor software
Google’s Driverless Car

Autonomous Parking

The Future of Autonomous Driving?

• “In 20 years I will trust my autonomous car more than I trust myself”
  – Sebastian Thrun

• “It won’t truly be an autonomous vehicle until you instruct it to drive to work and it heads to the beach instead.”
  – Brad Templeton

Harvesting Human Intelligence:
Anti-AI: CAPTCHA
Anti-AI

- Some AI problems are very hard
  - Vision, natural language understanding, …
- What do you do?
  - Give up?
  - Bang your head really hard?
  - Important lesson in life:
    - Turn hardness into something useful!
- Very hard for machine, trivial for human

CAPTCHA

Completely Automated Public Turing test to tell Computers and Humans Apart

- Yahoo!
- Google

CAPTCHA

- The “anti-Turing test”
- Tell human and machines apart, automatically
  - Deny spam-bots free email registration
  - Protect online poll from vote-bots
- By asking an “AI-complete” question

Random string → Distorted image → What do you see?

- Also audio Captcha’s, e.g., superimposed speakers
- http://www.captcha.net/

[Luis von Ahn, IAAI/IJCAI 2003 keynote]
Summary

AI is magical, but there’s no magic in AI

It’s about designing good models, and using optimization, probability, statistics, logic, etc. to develop efficient algorithms using (lots of) complex data.