CS 540, Section 2
Introduction to Artificial Intelligence

Chuck Dyer
Spring 2016

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


• 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
• Professor here since 1982
• 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)

Teaching Assistant
Fengan Li
• Hometown: Suzhou, China
• B.S., Beijing University
**Prerequisites**

- Basic JAVA programming (CS 302)
- Data structures (CS 367)
- Curiosity and enthusiasm

**Other Helpful Topics**
- Calculus (e.g., Math 221)
- Discrete Math (CS/Math 240)
- Probability (e.g., Math 431)
- Linear algebra (e.g., Math 340)
- Logic

**Workload**

- 5 homework assignments (~40% of grade)
  - Most with a programming part and written questions
  - 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 10, 7:15 – 9:15 p.m.
  - Final: Thursday, May 12, 2:45 – 4:45 p.m.
- Class attendance & participation (Piazza and in-class)

**Things to Do**

- Look at the course web page: [pages.cs.wisc.edu/~dyer/cs540](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](https://csl.cs.wisc.edu) and click “Activate Account”
- Sign up on Piazza
  - [https://piazza.com/wisc/spring2016/cs5402/home](https://piazza.com/wisc/spring2016/cs5402/home)
- Review Java, Eclipse IDE, and Linux
- Read Chapters 1 and 2 (focusing on 1.1, 2.1, 2.2, 2.3)

**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 filtering
- 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 (tentative)

- Problem solving as search (4 weeks)
- Machine learning (3 weeks)
- Probabilistic reasoning (3 weeks)
- Speech recognition (1 week)
- Computer vision (1 week)
- Representation and inference using logic (2 weeks)

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 Views of AI**

- Philosophy, ethics, religion
  - What is intelligence?
- Cognitive science, neuroscience, psychology, linguistics
  - Understand natural forms of intelligence
  - Learn principles of intelligent behavior
- Mathematics
  - Are there fundamental laws of intelligence?
- Engineering
  - Can we build intelligent devices and systems?
  - Autonomous and semi-autonomous systems for replicating human capabilities, enhancing human capabilities, improving task 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 Goggles)
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 use large, complex types of 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 it)
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; uncertainty often quantifiable, however, in terms of probabilities of each possible outcome.

AI 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.

AI Task Characteristics

• Is the 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".
AI Task Characteristics

• 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.

---

AI Paradigm

• Develop **general, efficient, satisficing** 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 Task Characteristics

• 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 Today

• A set of “tools” for computing a variety of useful classes of model types that represent information extracted from the 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.
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

- **Variable-based Models (Uncertainty)**
  - Solution is not a path but 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)**
  - Implicit representation of classes of objects
  - Deductive reasoning
  - Apps: Question answering systems, natural language understanding
  - Propositional logic, First-order logic

Some AI Applications

**Natural Language Understanding: Chatbots**

ALICE: 2004 Loebner Prize winner

ELIZA: psychotherapist

Valerie: CMU Robot Receptionist

Natural language processing, pattern matching

Valerie

Loebner Prize gold medal, awarded annually to best AI program
**A.L.I.C.E. Chatbot**

www.alicebot.org

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.

**A.L.I.C.E. talking to ELIZA**

ELIZA is a psychotherapist chatbot
http://www-ai.ijs.si/eliza/eliza.html

ALICE: Just keep talking to me as long as you can.
ELIZA: Do you wish to as long as me?
ALICE: OK, I will as long as you.
ELIZA: Do you wish to will as long as me?
ALICE: OK, I will will as long as you.
ELIZA: Do you wish to will will as long as me?
ALICE: OK, I will will will as long as you.
ELIZA: Do you wish to will will will will as long as me?
...

**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, …**

**Machine Translation**

The spirit is willing but the flesh is weak.  [Bible, Matthew 26:41]

Дух охотно готов но плоть слаба  Spirit is willingly ready but flesh it is weak
精神是愿意的但血肉是软弱的 The spirit is wants but the flesh and blood is weak
精神是愿意的但肉身是软弱的 Nind is rejoicing,, but the meat is weak
El alchol está dispuesto pero la carne es débil The alcohol is arranged but the meat is weak
El alcohol esta dispuesto pero la carne es débil The alcohol is ready nevertheless the meat is weak

- Statistical machine translation models
  translate.google.com
**Question Answering Systems**

Apple Siri

Speech recognition and language understanding

**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

**Game Playing: Chess**

- IBM Deep Blue vs. Kasparov, 1997/5
  - 6 games: K, D, draw, draw, draw, D
  - IBM stock up $18 billion

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

- 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

- Unsupervised learning
Face Detection in cameras for auto focusing

Also blink and smile detection!

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

iPhoto

Can be trained to recognize pets too!

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

Microsoft Kinect Camera

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

![Roomba demo](image)

Lawn Mowing Robots

Robomow

![Robomow](image)

Physical Assistants: Robots to Help the Elderly and Impaired

![Robots to Help the Elderly and Impaired](image)

Robots Playing Soccer

![Robots Playing Soccer](image)
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 2007 “Urban Challenge”

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

The 2005 “Grand Challenge” Race
Autonomous Parking

Google's Driverless Car

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

- 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

- Yahoo!
  ![Yahoo CAPTCHA](image1)
- Google
  ![Google CAPTCHA](image2)

Anti-AI

CAPTCHA

- Completely Automated Public Turing test to tell Computers and Humans Apart
  - Yahoo!
  ![Yahoo CAPTCHA](image3)
  - Google
  ![Google CAPTCHA](image4)
**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]

**reCAPTCHA**
- reCAPTCHA is a free service that improves the process of digitizing books by having humans decipher words that are not automatically recognized

**Summary**
There’s no magic in AI.
It’s all about designing good models, and using optimization, probability, statistics, logic, etc. to develop efficient algorithms using lots of data.