CSE 150
Introduction to Artificial Intelligence: Probabilistic Reasoning and Decision Making
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Outline

1. Logistics
2. What is Artificial Intelligence?
3. Philosophy
4. Foundations
5. History
6. State of the Art
7. Ethics
8. Course Preview
Logistics

• Waitlist
  – Hope someone drops
  – Limited by classroom size

• Taken a summer course before?
  – Easier? Harder? Same?
  – How many in one session?

• All relevant info on course webpage
  http://cseweb.ucsd.edu/~mfder/cse150.html

• Sign up on Piazza!
  https://piazza.com/ucsd/summer2014/cse150/
## Outline

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What is Artificial Intelligence (AI)?

• “the science & engineering of making intelligent machines”
  – John McCarthy: coined ‘AI’ in 1956
  – Intelligence: computational part of the ability to achieve goals in the world (but human vs. machine?)

• “computational rationality” (more precise, less threatening)
  “the study & design of intelligent/rational agents”
  – Russell+Norvig: perceive environment, act to achieve best (expected) outcome

• Alan Turing: Turing Test (1950)
  – satisfactory operational definition of intelligence
Turing Test

interrogator

human or computer?
Turing Test

• **Natural language processing (NLP)**
  communicate in English (own field)

• **Knowledge representation**
  store what it hears and knows (CSE 150)

• **Automated reasoning**
  use stored info to answer questions & draw new conclusions (CSE 150)

• **Machine learning**
  adapt to new circumstances, detect & extrapolate patterns (mostly CSE 151)
Turing Test

• **Turing’s prediction**

  computer will pass by the year 2000

  5 min convos, fool interrogator 30% of time
Turing Test

• **Turing’s prediction**
  computer will pass by the year 2000
  5 min convos, fool interrogator 30% of time

**Q:** Was Turing’s prediction correct?
Turing Test

- **Turing’s prediction**
  computer will pass by the year 2000
  5 min convos, fool interrogator 30% of time

**Q:** Was Turing’s prediction correct?

**A:** No.
Turing Test

• **Turing’s prediction**
  
  computer will pass by the year 2000
  5 min convos, fool interrogator 30% of time

**Q:** Was Turing’s prediction correct?
**A:** No.

**Q:** As of today, has a computer passed the test?
Turing's prediction

computer will pass by the year 2000
5 min convos, fool interrogator 30% of time

Q: Was Turing’s prediction correct?
A: No.

Q: As of today, has a computer passed the test?
A: No!
Turing Test

- Impractical & irrelevant?
  - AI researchers aren’t focused on passing it (let’s solve problems, not try to imitate humans)
  - planes are tested by how well they fly, not by comparing them to birds

- But! Clear & understandable example to aid in the discussion of the philosophy of AI
  - polite convention: if a machine acts as intelligently as a human, then it is as intelligent as a human
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Philosophy of AI

• **Weak AI**: can machines act intelligently?
• **Strong AI**: can machines really think?
  – **Turing** (1950): irrelevant; instead, polite convention & behavioral intelligence test
  – **Dijkstra** (1984): “The question of whether Machines Can Think ... is about as relevant as the question of whether Submarines Can Swim.”
    • Most would say submarines can’t swim, yet most would say airplanes can fly
    • No relevance to design & capabilities of system; only about word usage
Chinese Room

I'm just manipulating squiggles and squiggles to produce Chinese language behavior. But I don't understand Chinese. This rule book is in English.

在這屋裡的任何人或物，一定懂中文。

[Whoever or whatever is in that room is an intelligent Chinese speaker!]
Chinese Room

• **John Searle** (1980)
• Passes Turing Test, but does not *understand* anything of its inputs & outputs
  – running the right program does not necessarily generate understanding; **strong AI** is false
• One contention: **systems reply**
  – asking if human in room understands Chinese == asking if CPU can take cube roots
  – answers are “no”, but entire system *does* have the capacity in question
  – water is wet, but neither hydrogen nor oxygen is
Weak AI vs. Strong AI

• “Most AI researchers take the weak AI hypothesis for granted, and don’t care about the strong AI hypothesis—as long as their program works, they don’t care whether you call it a simulation of intelligence or real intelligence.”

~ Russell+Norvig, p. 1020
Other philosophical questions

• Can a machine have emotions?
• Can a machine be self aware?
• Can a machine be original or creative?
• Can a machine be benevolent or hostile?
• Can a machine have a soul?
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**Foundations of AI**

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<th>Philosophy</th>
<th>Mathematics</th>
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<td>Can we reason mechanically (follow formal rules to draw valid conclusions)? How does knowledge lead to action?</td>
<td>Logic: What are the formal rules to follow? Computation: What is computable? Tractable? Probability: How to reason with uncertain info?</td>
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<th>Economics</th>
<th>Neuroscience</th>
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<td>How to make decisions to maximize payoff? Other players: cooperate or conflict? What if payoff is in the distant future?</td>
<td>How do brains process information? “Brains cause minds”: a collection of simple cells can lead to thought, action, consciousness</td>
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<th>Computer engineering</th>
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<td>How do humans and animals think &amp; act? Cognitive science: how to model language, logical thinking, memory?</td>
<td>How to build an efficient computer? AI requires intelligence + artifact Solving problems in principle vs. in practice</td>
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<th>Linguistics</th>
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<tr>
<td>How artifacts operate under their own control? Design systems to maximize objective function over time</td>
<td>How does language relate to thought? Natural language processing (NLP) Understand: structure, subject, context</td>
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History of AI

- **Birth**: 1956
- **Gestation**: 1943-1955
- **Early buzz**: 1952-1969
- **Back to reality**: 1966-1973
- **Knowledge-based systems**: 1969-1979
- **Return of neural nets**: 1986-present
- **AI industry**: 1980-present
- **Intelligent agents**: 1995-present
- **Big Data**: 2001-present
- **Scientific method**: 1987-present
Aristotle (384 BC – 322 BC)

Syllogism:

All men are mortal.
Socrates is a man.
Therefore, Socrates is mortal.
<table>
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<th>Year</th>
<th>Event</th>
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<td>1943</td>
<td>McCullough &amp; Pitts model <strong>artificial neurons</strong> which are ON or OFF. Showed that any computable function could be computed by some network of connected neurons.</td>
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<td>1950</td>
<td>Minsky &amp; Edmonds build SNARC, first neural network computer.</td>
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<td>1950</td>
<td>Turing’s article “Computing Machinery and Intelligence”. Introduced Turing Test, machine learning, genetic algorithms, and reinforcement learning.</td>
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Gestation (1943-1955)
Birth 1956

1956: John McCarthy organizes 2-month, 10-man workshop at Dartmouth AI gained its name, mission, first success, major players Newell & Simon debuted the Logic Theorist, a reasoning program which proved mathematical theorems, some more elegantly
1952: Samuel’s **checkers-playing program**, soon learns to play at strong amateur level
1957: **General Problem Solver** (GPS) solves puzzles like humans do
1958: McCarthy invents **Lisp** (dominant AI language for next 30 yrs)
1959: McCarthy & Minsky found **MIT AI lab**
1959: Gelernter’s **Geometry Theorem Prover**
1963: McCarthy starts **Stanford AI lab**
1963: Slagle’s **SAINT** solves calculus integration problems
1967: Bobrow’s **STUDENT** solves algebra story problems
1968: Evans’ **ANALOGY** solves geometric analogy problems in IQ tests
History of AI

1958: Simon & Newell: “Within 10 yrs, a computer will be world’s chess champion, discover & prove a new mathematical theorem”

1965: Simon: “Within 20 yrs, machines will be capable of doing any work a man can do”

1967: Minsky: “Within a generation, the problem of creating artificial intelligence will substantially be solved”

1970: Minsky: “In 3-8 yrs we will have a machine w/ the general intelligence of an average human being”

Back to reality
1966-1973

• Predictions too lofty
• Programs knew nothing of subject matter
  Russian re-translation: “the spirit is willing but the flesh is weak” → “the vodka is good but the meat is rotten”
• Limited computer power & intractability
• **AI Winter**: funding dried up
From general-purpose reasoning to domain-specific applications

1969: DENDRAL infers molecular structure from mass spectrum
1972: MYCIN diagnoses blood infections, performs as well as some experts
1972: Prolog developed ("Programming in logic")
**History of AI**

**AI industry**: few million $ in 1980 to billions in 1988

1982: Expert system R 1 at Digital Equipment Corporation (DEC), helps configure orders for new computer systems

1986: R 1 saves DEC ~$40M/yr

1988: DEC has 40 expert systems

DuPont has 100 in use, 500 in development; saves ~$10M/yr

Second AI winter: companies fail to meet lofty goals & expectations
History of AI

- **Connectionist** models instead of symbolic models, logic
- Widely popular today

• Build on existing theories
• Rigorous theorems, experimental evidence over intuition
• Real-world applications over toy examples
• Public data & code

Return of neural nets
1986-present

Scientific method
1987-present
History of AI

- Economist's rational agent + computer science's object/model = intelligent agent
- **Internet:** search engines, recommender systems, Web site aggregators

- 60-yr history of CS: focus on *algorithm*; now, focus on *data*
- Trillions of words of English text, billions of images, billions of base pairs in genomic sequences
- Ex: Hays & Efros (2007), filling in holes in a photo
  - 10k photos: poor performance
  - 2M photos: excellent performance
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State of the Art

DART (1991)

Spam filtering (1998)

Deep Blue (1997)

Roomba (2002)


Mars rovers (2003, 2011)

Kinect (2010)
State of the Art

- **Dynamic Analysis & Replanning Tool (DART)**
  - Automated logistics planning & scheduling for transportation
  - Deployed in Gulf War before Desert Storm
  - Accounted for 50k vehicles, cargo, people; starting points, destinations, routes, conflict resolution
  - Generated a (better!) plan in hours instead of weeks
  - **DARPA**: this 1 project more than paid back its 30-yr investment in AI
State of the Art

- Deployed today by large webmail providers
- Classify billions of emails as spam every day
- Adapt to spammers’ evolving tactics

DART (1991)

Spam filtering (1998)

Roomba (2002)


Mars rovers (2003, 2011)
State of the Art

- **Kinect** released Nov 2010 for Xbox 360
- Natural user interface using gestures and spoken commands
- RGB camera, depth sensor, and multi-array microphone
- Full-body 3D motion capture, facial recognition, and voice recognition
State of the Art

- **Deep Blue**: chess-playing computer by IBM
- “Chess is the Drosophila of AI” (A. Kronrod)
- **Feb 1996**: Lost 2-4 to world champion Garry Kasparov
- **May 1997**: Won rematch 3.5-2.5; first computer to defeat a world champion
- Game 1, 44th move: bug! Picked a move *completely at random* as last resort
  - Inconsequential: game was already lost
  - Bug fixed next day
  - Kasparov, mistakenly: “superior intelligence”
  - Anxiety to blame for Game 2 loss?
- Game 2: Kasparov accused IBM of cheating (human intervention mid-game)
- Kasparov demanded rematch, IBM refused
- Ploy by IBM to boost stock? $18B jump
State of the Art

- **Roomba & PackBot** by iRobot
- **10M Roomba units** sold worldwide (Feb 2014)
- **3k PackBots** deployed (Feb 2010)
- 2k+ PackBots in Iraq & Afghanistan handle hazardous materials, clear explosives, identify location of snipers
- First robots to enter Fukushima nuclear plant after 2011 tsunami & earthquake
- Brazilian gov’t paid $7.2M for 30 PackBots to boost security & examine suspicious objects at 2014 World Cup
State of the Art

- **Opportunity & Curiosity**
- Both still active today
- Climate & geology
- Water? Life?
- Prepare for human exploration

Mars rovers (2003, 2011)
State of the Art

Stanley (2005)

Boss (2007)

Google Self-Driving Car (2010)

Siri (2011)

Amazon Prime Air (2015?)

Watson (2011)
State of the Art


- **Stanley** (Stanford): won 2005 DARPA Grand Challenge, $2M 132-mile course in Mojave desert, 22mph
- **Boss** (CMU): won 2007 DARPA Grand Challenge (“Urban Challenge”), $2M drove in closed Air Force base, obeyed traffic laws, avoided pedestrians & other vehicles
- **Google Self-Driving Car**
  - ~$150M in equipment; 64-beam laser for inch-precision 3D mapping
  - April 2014: vehicles logged 700k miles
  - May 2014: ~200 new prototypes w/out steering wheel or pedals, 200yd sensor radius, 25mph top speed
State of the Art

- Testing autonomous cars legal in 4 states: NV, FL, CA, MI
- Predictions
  - IEEE (2013): by 2040, 75% of all vehicles will be autonomous
  - PricewaterhouseCoopers (2013):
    - Traffic accidents: 10.8M → 1.1M
    - Congestion-based wasted fuel: 1.8B gal → 190M gal
    - US vehicle fleet: 245M → 2.4M
State of the Art


• **Siri** debuted Oct 4, 2011 on iPhone 4S
• Speech recognition, conversational interaction, integration w/ apps & services
• 10 languages supported
• Banks, airlines, etc: entire conversations conducted using automated speech recognition & dialog management system
State of the Art

- **Watson**: AI QA system by IBM
- **Software**: Java, C++, Prolog; Linux; Hadoop
- **Hardware**: $3M, 500 GB/s; cluster of 90 servers; 2,880 cores, 3.5 GHz; 16 TB RAM
- **Data**: 4 TB of structured & unstructured content, including all of Wikipedia; all in RAM
- Final 2-game result:
  1. **Watson**: $77,147
  2. **Ken Jennings**: $24,000
  3. **Brad Rutter**: $21,600
- QA significantly harder than document search
- Jan 2014: IBM Watson Group; $1B investment; goal is $10B in annual revenue w/in 10 yrs
- **Applications**: medicine & healthcare, finance, business, education, development in Africa, military (help veterans transition into civilian life), retail sales, legal research, etc.
State of the Art


Siri (2011)  Amazon Prime Air (2015?)

• Announced Dec 1, 2013
• 30-min delivery, 10-mile radius of fulfillment center, less than 5 lbs
• UAV not yet legal in US
• “We hope the FAA's rules will be in place as early as sometime in 2015. We will be ready at that time.”
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Ethics & risks of AI

- People might lose their jobs to automation
- People might have too much (or little) leisure time
- People might lose their sense of being unique
- AI systems might be used toward undesirable ends
- The use of AI systems might result in a loss of accountability
• The success of AI might mean the end of the human race
  – ultraintelligent machine: a machine that can far surpass all the intellectual activities of any man (Good, 1965)
    • thus could design even better machines (recursive self-improvement)
  – Singularity: AI surpasses human intelligence
    • “The Singularity will allow us to transcend these limitations of our biological bodies and brain [...] By the end of this century, the nonbiological portion of our intelligence will be trillions of trillions of times more powerful than unaided human intelligence.” (Ray Kurzweil, The Singularity is Near, 2005)
Three Laws of Robotics

• If ultraintelligent machines are possible, humans should design their predecessors to treat us well so that they design themselves to treat us well, too

• Isaac Asimov’s Three Laws of Robotics (1942)
  1. A robot may not injure a human being or, through inaction, allow a human being to come to harm.
  2. A robot must obey orders given to it by human beings, except where such orders would conflict with the First Law.
  3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.
Sources / Reading (& watching)

- Russell+Norvig
  - Ch 1: Introduction
  - Ch 26: Philosophical Foundations
- Wikipedia
- Norvig: The unreasonable effectiveness of data
  https://www.youtube.com/watch?v=yvDCzhbjYWs
- Google self-driving car test
  https://www.youtube.com/watch?v=cdgQpa1pUUE
- Watson on Jeopardy!
  https://www.youtube.com/watch?v=lI-M7O_bRNg
- TED Talk: Get ready for hybrid thinking (Ray Kurzweil, March 2014)
  https://www.youtube.com/watch?v=PVXQUItNEDQ
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Probabilistic reasoning

Example: **medical diagnosis**
- **Knowledge representation**
  diseases cause symptoms
- **Modeling uncertainty**
  some diseases, symptoms more likely than others
- **Reasoning**
  infer diseases from symptoms
- **Probability**
  quantitative, self-consistent framework that captures common sense patterns of reasoning
How do graphs represent correlation, causation, statistical independence?
Marriage of probability and graph theory
Classification

Example: spam filtering

Input: email message
Output: \{spam, not spam\}

How to represent the input? Convert text to vector of word counts

\[ V = \text{vocabulary (dictionary) size} \]
\[ c_i = \# \text{times } i^{\text{th}} \text{ word appears in email} \]
Classification

Graphical model

- Certain words more likely in spam
- How to quantify? Estimate?
Sequential modeling

How to model systems where “state” changes over time (or has a similarly extended representation)?

Example:  **text (written language)**

“state” = word

Which sentence is more likely?

(1) Mary had a little lamb
(2) Colorless green ideas sleep furiously

→ Markov models of statistical language processing
Graphical models

\[ w_l = \text{word at } l^{th} \text{ position in sentence} \]
(with V possible values)

(A)  \hspace{1cm} (B)

Model A is obviously wrong, over-simplified, but easier to estimate
Model B is rich but harder to estimate
Limited rationality: acting appropriately under computational constraints
Sequential modeling

Example: **speech (spoken language)**
  - **states** = words (or syllables, smaller units of speech)
  - **observations** = sounds, waveforms

How to infer words from waveforms?

→ **hidden Markov models for speech recognition**
Example: **robot navigation**

2D grid world
- **states** = cells of grid
- **actions** = N, S, E, W
- noisy dynamics in world

Learning = feedback from environment
- delayed vs. immediate
- evaluative vs. instructive

Generally: how autonomous agents learn from experience?

→ **Markov decision processes (reinforcement learning)**
Core ideas of modern AI

1. Probabilistic models of uncertainty
2. Learning as optimization

Variable $\Theta$ parameterizes agent’s model / predictions / behaviors

Function $f(\Theta)$ measures agent’s performance
Core ideas of modern AI

Knowledge as predictions (dynamic), not facts (static)

- **Classical AI:** logic, symbolic manipulation
  - **fact #1:** All rabbits have fur.
  - **fact #2:** Some pets are rabbits
    - Some pets have fur.

- **Modern AI:** agent-centric
  - **prediction:** if action $a$, then observe consequence with some probability
Agents

- "Embodied" agents
  - unmanned aerial vehicles (UAVs)
  - elevators
- "Embedded" agents
  - game-playing AI
  - telephone operators
- Agent function: percepts to action

\[ f : P^* \rightarrow A \]
Prolog example

mother_child(kris, katie).
father_child(charlie, katie).
father_child(charlie, david).
father_child(chuck, charlie).
sibling(X, Y) :- parent_child(Z, X), parent_child(Z, Y).
parent_child(X, Y) :- father_child(X, Y).
parent_child(X, Y) :- mother_child(X, Y).

?- sibling(katie, david).
Yes
Classical vs. Modern

**Classical AI**
- hard to state informal (and uncertain!) knowledge in formal logical notation
- computationally impractical w/ only 100s of rules

**Modern AI**
+ correct inference only *part* of rationality
+ mathematically well defined & general, not based on human behavior or thought
Peeking ahead ...

- **Bayesian network**
  - a probabilistic graphical model that represents a set of random variables and their conditional dependencies via a directed acyclic graph (DAG)
  - allows efficient representation of, and rigorous reasoning with, uncertain knowledge
Why won’t my car start?!

Car Diagnosis 2

Developed by Brent Boerlage

http://www.norsys.com/netlibrary/index.htm
Troubleshoot printer in Windows 95

http://www.norsys.com/netlibrary/index.htm

Win95pts
Developed by Microsoft
Edited for style by Norsys Software Corp.