Section Q course website:

http://slazebni.cs.illinois.edu/fall17/
Last time: What is AI?
Last time: What is AI?

Four possible definitions (textbook ch. 1):

Thinking humanly

Thinking rationally

Acting humanly

Acting rationally

Source: Berkeley CS188 materials
AI definition 4: Acting rationally

• **A rational agent** acts to optimally achieve its goals
  • Goals are application-dependent and are expressed in terms of the **utility of outcomes**
  • Being rational means **maximizing your utility** or **expected utility** in the presence of uncertainty
  • In practice, utility optimization is subject to the agent’s computational constraints (**bounded rationality** or **bounded optimality**)
Utility maximization formulation

• Advantages
  • Definition is about the agent’s decisions/actions, not the cognitive process behind them
  • Generality: goes beyond explicit reasoning, and even human cognition altogether
  • Practicality: can be adapted to many real-world problems
  • Naturally accommodates uncertainty
  • Amenable to good scientific and engineering methodology
  • Avoids philosophy and psychology

• Disadvantages?
  • It may be hard to formulate utility functions, especially for complex open-ended tasks
  • The AI may end up “gaming” the utility function, or its operation may have unintended consequences
  • Has limited applicability to humans
Humans vs. rationality

Predictably Irrational: The Hidden Forces That Shape Our Decisions

Dan Ariely

Revised and Expanded Edition

New York Times Bestseller
AI: History and themes
What are some successes of AI today?
IBM Watson and “cognitive computing”

- 2010 NY Times article, trivia demo
- February 2011: IBM Watson wins on Jeopardy
- Since then: Watson Analytics, social services, personal shopping, health care
Self-driving cars

If the age of self-driving cars is upon us, what’s keeping them off the road?
The Guardian - 9 hours ago
Sitting in the passenger seat of Google’s self-driving car is a less bizarre experience than sitting in the driving seat, but it’s still unsettling. In the ...

Legislators rush to keep up with self-driving cars
East Valley Tribune - 1 hour ago
There apparently are no laws which would prohibit manufacturers from marketing self-driving cars today to consumers. And nothing keeps ...

How will self-driving cars affect your insurance?
The Conversation UK - 1 hour ago
And software bugs in self-driving cars could create a new reason manufacturers might have to shoulder the cost of crashes. Yet if drivers ...

From Microsoft to Self-Driving Cars, Invention Springs From Data
Adweek - 16 hours ago
The product data arms race is also at play in the nascent but exploding space of self-driving cars. While design will certainly be important, ...

If Uber and Lyft switch to self-driving cars, what about the drivers?
Digital Trends - Aug 21, 2016
Uber and Lyft have tens of thousands of drivers in the U.S. alone. The two ride-sharing companies have each been in the news recently for their ...

Ford Promises Fleets of Driverless Cars Within Five Years
In the race to develop driverless cars, several automakers and technology companies are already testing vehicles that pilot themselves on ...

The summer that changed everything for Uber: China, self-driving cars...
VentureBeat - 3 hours ago

Want a ride? Ford hopes to race ahead of self-driving pack sans pedals
Chicago Tribune - Aug 17, 2016

Uber is about to start giving rides in self-driving cars
Los Angeles Times - Aug 18, 2016
The robot cars aren’t coming. The robot cars are here. A fleet of Fords and Volvos, capable of driving themselves, is fully equipped and ready to ...

Self-driving cars safe, say firms developing such vehicles here
The Straits Times - Aug 20, 2016
Despite recent accidents involving driverless cars in the United States, two companies involved in developing such vehicles here said they are ...

Here’s how Ford’s self-driving cars will work
Business Insider - Aug 20, 2016
On Tuesday, the automaker announced that it aims to roll out an autonomous taxi fleet in at least one city in 2021. Ford said its driverless cars will have level 4 ...

Uber Buys Self-Driving Truck Biz
SciTech Today - Aug 21, 2016
Uber Buys Self-Driving Truck Biz and Tests Autonomous Cars .... Ford’s approach to the autonomous car breaks from many other companies, ...

Google News snapshot as of August 22, 2016
Self-driving cars

Google News snapshot as of August 28, 2017
Speech and natural language

**Skype Translator**

Break down the language barrier with your friends, family and colleagues.

Our online translator can help you communicate in 7 languages for voice calls, and in more than 50 languages while instant messaging.

Skype Translator uses machine learning. So the more you use it, the better it gets. Thanks for being patient as the technology graduates from Preview mode.


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**Google Translate App**

- Translate between 103 languages by typing
- Offline: Translate 52 languages when you have no Internet
- Instant camera translation: Use your camera to translate text instantly in 30 languages
- Camera Mode: Take pictures of text for higher-quality translations in 37 languages
- Conversation Mode: Two-way instant speech translation in 32 languages
- Handwriting: Draw characters instead of using the keyboard in 93 languages

Vision

Computer Eyesight Gets a Lot More Accurate,
NY Times Bits blog, August 18, 2014
Vision

Facebook accessibility tools for the visually impaired

AI beats human pathologists at detecting cancer

Technology behind Snapchat lenses
Games

• **1997:** IBM’s Deep Blue defeats the reigning world chess champion Garry Kasparov
  
  • **1996: Kasparov Beats Deep Blue**
    “I could feel – I could smell – a new kind of intelligence across the table.”
  
  • **1997: Deep Blue Beats Kasparov**
    “Deep Blue hasn't proven anything.”

• **2007:** [Checkers is solved](#)
  
  • Though checkers programs had already been beating the best humans for at least a decade

• **2016:** [AlphaGo computer beats Go grandmaster Lee Sedol 4-1](#)

• **2017:** [CMU’s Libratus system beats four of the best human players at no-limit Texas Hold’em poker](#)
Robotics

• Autonomous vehicles
  • DARPA Grand Challenge
  • Self-driving cars
  • Vehicles for exploring space, hazardous environments
  • Autonomous drones

• Robot soccer
  • RoboCup

• Personal robotics
  • Humanoid robots
  • Robotic pets
  • Personal assistants?
DARPA Robotics Challenge (2015)

The Most Hilarious Robo-Falls from the DARPA Robotics Challenge


https://www.youtube.com/watch?v=g0TaYhpOfo
Towel-folding robot

YouTube Video

- J. Maitin-Shepard, M. Cusumano-Towner, J. Lei and P. Abbeel, Cloth Grasp Point Detection based on Multiple-View Geometric Cues with Application to Robotic Towel Folding, ICRA 2010
- More clothes folding
Towel-folding robot

U.S. Senator Calls Robot Projects Wasteful. Robots Call Senator Wasteful

By Erico Guizzo
Posted 14 Jun 2011 | 13:58 GMT

Tom Coburn, a senator from Oklahoma, and PR2, a robot from California.

Deep sensorimotor learning

YouTube video

S. Levine, C. Finn, T. Darrell and P. Abbeel,
End-to-end training of deep visuomotor policies, JMLR 2016
Mathematics

• In 1996, a computer program written by researchers at Argonne National Laboratory proved a mathematical conjecture unsolved for decades
  - NY Times story: “[The proof] would have been called creative if a human had thought of it”

• Mathematical software:

\[
\begin{align*}
\partial_r^2 u &= - \left[ E' - \frac{l(l+1)}{r^2} - r^2 \right] u(r) \\
e^{-2s} \left( \partial_s^2 - \partial_s \right) u(s) &= - \left[ E' - l(l+1)e^{-2s} - e^{2s} \right] u(s) \\
e^{-2s} \left[ e^{\frac{1}{2} s} \left( e^{-\frac{1}{2} s} u(s) \right)'' - \frac{1}{4} u \right] &= - \left[ E' - l(l+1)e^{-2s} - e^{2s} \right] u(s) \\
e^{-2s} \left[ e^{\frac{1}{2} s} \left( e^{-\frac{1}{2} s} u(s) \right)'' \right] &= - \left[ E' - \left( l + \frac{1}{2} \right)^2 e^{-2s} - e^{2s} \right] u(s) \\
v'' &= -e^{2s} \left[ E' - \left( l + \frac{1}{2} \right)^2 e^{-2s} - e^{2s} \right] v
\end{align*}
\]
Logistics, scheduling, planning

- During the 1991 Gulf War, US forces deployed an AI logistics planning and scheduling program that involved up to 50,000 vehicles, cargo, and people.
- NASA’s Remote Agent software operated the Deep Space 1 spacecraft during two experiments in May 1999.
- In 2004, NASA introduced the MAPGEN system to plan the daily operations for the Mars Exploration Rovers.
## Origins of AI: Early excitement

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
</table>
| 1940s | First model of a neuron (W. S. McCulloch & W. Pitts)  
          Hebbian learning rule  
          Cybernetics                                                                 |
| 1950s | Turing Test  
          Perceptrons (F. Rosenblatt)  
          Computer chess and checkers (C. Shannon, A. Samuel)  
          Machine translation (Georgetown-IBM experiment)  
          Theorem provers (A. Newell and H. Simon,  
                         H. Gelernter and N. Rochester) |
| 1956  | **Dartmouth meeting: “Artificial Intelligence” adopted**                                   |
“It is not my aim to surprise or shock you – but … there are now in the world machines that think, that learn and that create. Moreover, their ability to do these things is going to increase rapidly until – in a visible future – the range of problems they can handle will be coextensive with the range to which human mind has been applied. More precisely: within 10 years a computer would be chess champion, and an important new mathematical theorem would be proved by a computer.”

• Prediction came true – but 40 years later instead of 10
NEW NAVY DEVICE LEARNS BY DOING

Psychologist Shows Embryo of Computer Designed to Read and Grow Wiser

WASHINGTON, July 7 (UPI) — The Navy revealed the embryo of an electronic computer today that it expects will be able to walk, talk, see, write, reproduce itself and be conscious of its existence.

The Navy today showed for the first time the embryonic version of a Perceptron computer that is capable of learning by experience. The Perceptron, which is still under development by the Navy, is designed to perform tasks that require human-like intelligence.

Dr. Frank Rosenblatt, designer of the Perceptron, conducted the demonstration. He said the machine would be the first device to think as the human brain does. As do human beings, Perceptron will make mistakes at first, but will grow wiser as it gains experience, he said.

Dr. Rosenblatt, a research psychologist at the Cornell Aeronautical Laboratory, Buffalo, said Perceptrons might be fired to the planets as mechanical space explorers.

Without Human Controls

The Navy said the perceptron would be the first non-living mechanism “capable of receiving, recognizing and identifying its surroundings without any human training or control.”

The “brain” is designed to remember images and information it has perceived itself. Ordinary computers remember only what is fed into them on punch cards or magnetic tape.

Later Perceptrons will be able to recognize people and call out their names and instantly translate speech in one language to speech or writing in another language, it was predicted.

Mr. Rosenblatt said in principle it would be possible to build brains that could reproduce themselves on an assembly line and which would be conscious of their existence.

In today’s demonstration, the “704” was fed two cards, one with squares marked on the left side and the other with squares on the right side.

Learns by Doing

In the first fifty trials, the machine made no distinction between them. It then started registering a “Q” for the left squares and “O” for the right squares.

Dr. Rosenblatt said he could explain why the machine learned only in highly technical terms. But he said the computer had undergone a “self-induced change in the wiring diagram.”

The first Perceptron will have about 1,000 electronic “association cells” receiving electrical impulses from an eye-like scanning device with 400 photo-cells. The human brain has 10,000,000,000 responsive cells, including 100,000,000 connections with the eyes.
Harder than originally thought

• 1966: **Eliza** chatbot (Weizenbaum)
  • “... mother ...” → “Tell me more about your family”
  • “I wanted to adopt a puppy, but it’s too young to be separated from its mother.”

• 1954: **Georgetown-IBM experiment**
  • Completely automatic translation of more than sixty Russian sentences into English
  • Only six grammar rules, 250 vocabulary words, restricted to organic chemistry
  • Promised that machine translation would be solved in three to five years (press release)
  • Automatic Language Processing Advisory Committee (ALPAC) report (1966): machine translation has failed
    • “The spirit is willing but the flesh is weak.” →
    • “The vodka is strong but the meat is rotten.”
Blocks world (1960s – 1970s)

Larry Roberts, MIT, 1963
History of AI: From excitement to disillusion

1940s
- First model of a neuron (W. S. McCulloch & W. Pitts)
- Hebbian learning rule
- Cybernetics

1950s
- Turing Test
- Perceptrons (F. Rosenblatt)
- Computer chess and checkers (C. Shannon, A. Samuel)
- Machine translation (Georgetown-IBM experiment)
- Theorem provers (A. Newell and H. Simon, H. Gelernter and N. Rochester)

Late 1960s
- Machine translation deemed a failure
- Neural nets deprecated (M. Minsky and S. Papert, 1969)*

Early 1970s
- Intractability is recognized as a fundamental problem

Late 1970s
- The first AI winter

* A sociological study of the official history of the perceptrons controversy
<table>
<thead>
<tr>
<th>Time Period</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980s</td>
<td>Expert systems boom</td>
</tr>
<tr>
<td>Late 1980s-</td>
<td>Expert system bust; the second AI winter</td>
</tr>
<tr>
<td>Early 1990s</td>
<td></td>
</tr>
<tr>
<td>Mid-1980s</td>
<td>Neural networks and back-propagation</td>
</tr>
<tr>
<td>Late 1980s</td>
<td>Probabilistic reasoning</td>
</tr>
<tr>
<td>1990s</td>
<td>Machine learning becomes dominant</td>
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<tr>
<td>Late 2000s</td>
<td>Big data</td>
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<tr>
<td>2010s</td>
<td>Deep learning</td>
</tr>
<tr>
<td></td>
<td>New industry boom</td>
</tr>
</tbody>
</table>

[History of AI on Wikipedia](#)

[Building Smarter Machines: NY Times Timeline](#)
What accounts for recent successes in AI?

• Faster computers
  • The IBM 704 vacuum tube machine that played chess in 1958 could do about **50,000 calculations per second**
  • Deep Blue could do **50 billion calculations per second** – a million times faster!

• Dominance of statistical approaches, machine learning

• Big data

• Crowdsourcing
Historical themes

- Boom and bust cycles
  - Periods of (unjustified) optimism followed by periods of disillusionment and reduced funding
A view of the current AI boom

A view of the current AI boom

Historical themes

• Boom and bust cycles
  • Periods of (unjustified) optimism followed by periods of disillusionment and reduced funding

• Silver bulletism (Levesque, 2013):
  • “The tendency to believe in a silver bullet for AI, coupled with the belief that previous beliefs about silver bullets were hopelessly naïve”

• Image problems
  • AI effect: As soon as a machine gets good at performing some task, the task is no longer considered to require much intelligence
  • AI as a threat?
Al weapons are a threat to humanity, warn Hawking, Musk and Wozniak

by Jason Murdock 28 Jul 2015

The rush to develop autonomous weapons will cause a global arms race, according to an open letter signed by over 1,000 artificial intelligence (AI) researchers, academics and computer scientists.

The letter has been signed by high-profile figures including physicist Stephen Hawking, Tesla chief executive Elon Musk and Apple co-founder Steve Wozniak, and argues AI has reached a point where deployment of robotic weapons is feasible within years.

Autonomous weapons are described in the letter as those that "select and engage targets without human intervention".

This includes, for example, armed quadcopters searching and eliminating targets that meet pre-defined criteria, but not remote controlled missiles or piloted drones that still have human involvement.

The letter was presented at this year's International Joint Conferences on AI in Buenos Aires, and argues that there are advantages to replacing human soldiers with machines but that doing so would "lower the threshold" for warfare.
Will robots take our jobs? Experts can't decide

A new report from Pew Research brings together almost 2,000 experts to comprehensively assess the effect of robots on the workplace

Alex Hern
@alexhem

Wednesday 6 August 2014 10.00 EDT

Historical themes

- **Moravec’s paradox**
  - “It is comparatively easy to make computers exhibit adult level performance on intelligence tests or playing checkers, and difficult or impossible to give them the skills of a one-year-old when it comes to perception and mobility”
  [Hans Moravec, 1988]
  - Why might this be?
    - Early AI researchers concentrated on the tasks that they themselves found the most challenging, abilities of animals and two-year-olds were overlooked
    - We are least conscious of what our brain does best
    - Sensorimotor skills took millions of years to evolve, whereas abstract thinking is a relatively recent development
Two brain systems?

- **System 1:** fast, automatic, subconscious, emotional
  - Detect hostility on a face or in a voice
  - Orient to the source of a sudden sound
  - Answer to 2+2=?
  - Read words on large billboards
  - Drive on an empty road

- **System 2:** slow, effortful, logical, calculating, conscious
  - Focus on the voice of a particular person in a crowded and noisy room
  - Search memory to identify a melody
  - Count the occurrences of the letter a on a page
  - Compare two washing machines for overall value
  - Fill out a tax form
  - Check the validity of a complex logical argument

In this class

- Part 1: sequential reasoning

- Part 2: pattern recognition and learning
Philosophy of this class

• Learn to program computers to solve hard problems traditionally thought to require human intelligence
• Adopt the “rational agent” definition of AI
• Follow a sound scientific/engineering methodology
  • Consider limited application domains
  • Use well-defined input/output specifications
  • Define operational criteria amenable to objective validation
  • Zero in on essential problem features
  • Focus on principles and basic building blocks
In-depth reading: Behind the technologies

•  **The Man Who Tried to Redeem the World Through Logic** (Nautilus on Walter Pitts)
•  **How Checkers Was Solved** (The Atlantic)
•  **The Great AI Awakening** (New York Times Magazine on Google machine translation)
•  **The Doomsday Invention** (New Yorker on Nick Bostrom and superintelligence)
•  **AI vs. MD** (New Yorker on automated medical diagnosis)