

# CS440/ECE448: Artificial Intelligence

---

**Section Q course website:**

**<http://slazebni.cs.illinois.edu/fall16/>**

# Last time: What is AI?

---

Definitions from Chapter 1 of the textbook:

<b>1. Thinking humanly</b>	<b>2. Acting humanly</b>
<b>3. Thinking rationally</b>	<b>4. Acting rationally</b>

# 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 (expected) utility**
- This definition of rationality only concerns the decisions/actions that are made, not the cognitive process behind them
- In practice, utility optimization is subject to the agent's computational constraints (**bounded rationality** or **bounded optimality**)

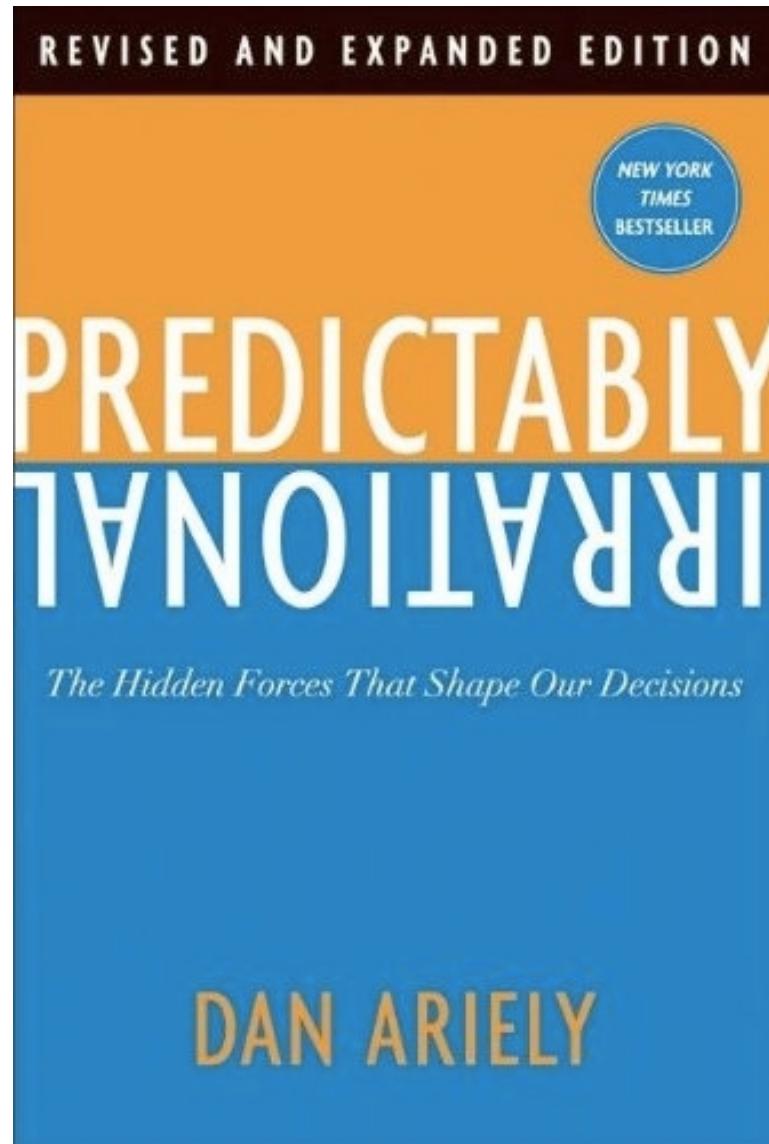
# Utility maximization formulation

---

- Advantages
  - 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

---



# AI: History and themes

---



[Image source](#)

# 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 ...  
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 ridesharing companies have each been in the news recently for their ...  
The summer that changed everything for Uber: China, **self-driving** ...  
In-Depth - VentureBeat - 3 hours ago

[View all](#)



Ford Promises Fleets of **Driverless Cars** Within Five Years  
New York Times - Aug 16, 2016  
In the race to develop **driverless cars**, several automakers and technology companies are already testing vehicles that pilot themselves on ...  
Want a ride? Ford hopes to race ahead of **self-driving** pack sans ...  
Opinion - Chicago Tribune - Aug 17, 2016

[View all](#)



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 ...  
How Pittsburgh Birthed the Age of the **Self-Driving Car**  
In-Depth - WIRED - Aug 19, 2016

[View all](#)



**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  
Sci-Tech 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

# 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.

<https://www.skype.com/en/features/skype-translator/>



***Hallo, hola, olá to the new, more powerful Google Translate app***

---

Posted: Wednesday, January 14, 2015

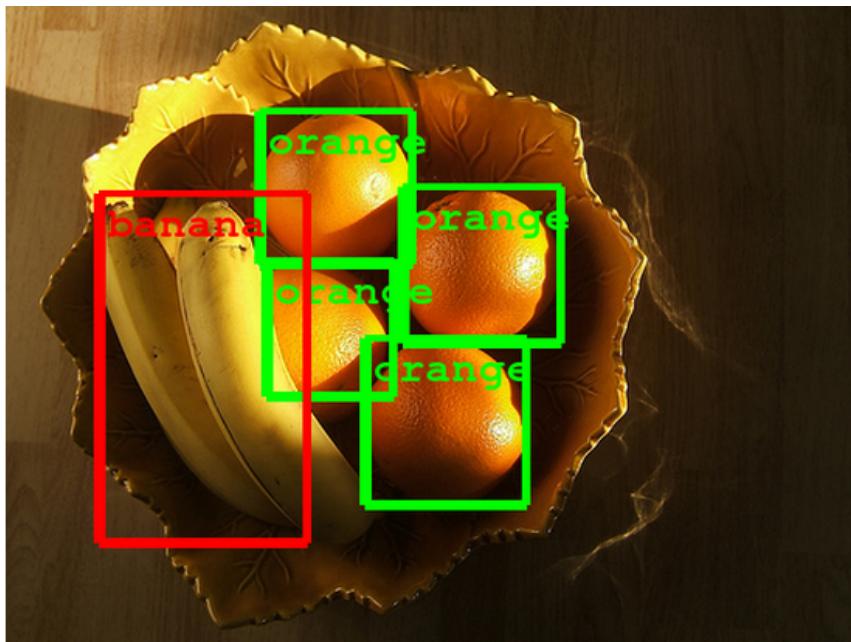
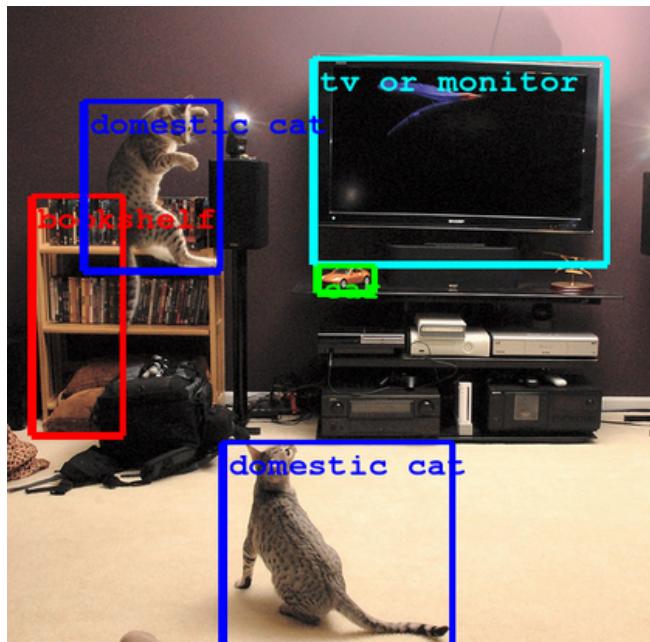
---

- Instant translation with Word Lens
- Have a conversation with Google Translate

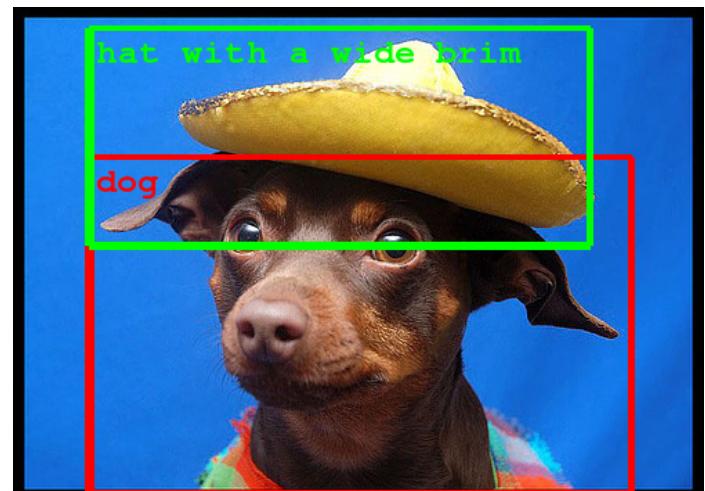
<http://googleblog.blogspot.com/2015/01/hallo-hola-ola-more-powerful-translate.html>

# Vision

---



- [Computer Eyesight Gets a Lot More Accurate](#),  
NY Times Bits blog, August 18, 2014
- [Building A Deeper Understanding of Images](#),  
Google Research Blog, September 5, 2014
- [Baidu caught gaming recent supercomputer performance test](#), Engadget, June 3, 2015



# Games

---

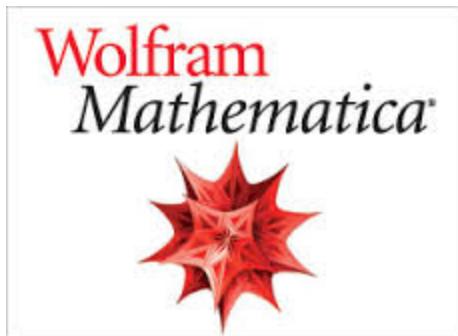
- 1997: IBM's Deep Blue defeats the reigning world chess champion Garry Kasparov
  - **1996: Kasparov Beats Deep Blue**  
“I could feel – I could smell – a new kind of intelligence across the table.”
  - **1997: Deep Blue Beats Kasparov**  
“Deep Blue hasn't proven anything.”
- 2007: Checkers is solved
  - Though checkers programs had been beating the best human players for at least a decade before then
- 2014: Heads-up limit Texas Hold-em poker is solved
  - First game of imperfect information
- 2016: AlphaGo computer beats Go grandmaster Lee Sedol 4-1



# 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:



$$\begin{aligned}\partial_r^2 u &= - \left[ E' - \frac{l(l+1)}{r^2} - r^2 \right] u(r) \\ e^{-2s} (\partial_s^2 - \partial_s) u(s) &= - [E' - l(l+1)e^{-2s} - e^{2s}] u(s) \\ e^{-2s} \left[ e^{\frac{1}{2}s} \left( e^{-\frac{1}{2}s} u(s) \right)'' - \frac{1}{4} u \right] &= - [E' - l(l+1)e^{-2s} - e^{2s}] u(s) \\ e^{-2s} \left[ e^{\frac{1}{2}s} \left( e^{-\frac{1}{2}s} u(s) \right)'' \right] &= - \left[ E' - \left( l + \frac{1}{2} \right)^2 e^{-2s} - e^{2s} \right] u(s) \\ v'' &= -e^{2s} \left[ E' - \left( l + \frac{1}{2} \right)^2 e^{-2s} - e^{2s} \right] v\end{aligned}$$

# 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

# 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)

JUN 5, 2015 @ 3:24 PM

NEW TECHNOLOGY ROBOTS DARPA ROBOTS DARPA ROBOTICS CHALLENGE

## The Most Hilarious Robo-Falls from the DARPA Robotics Challenge

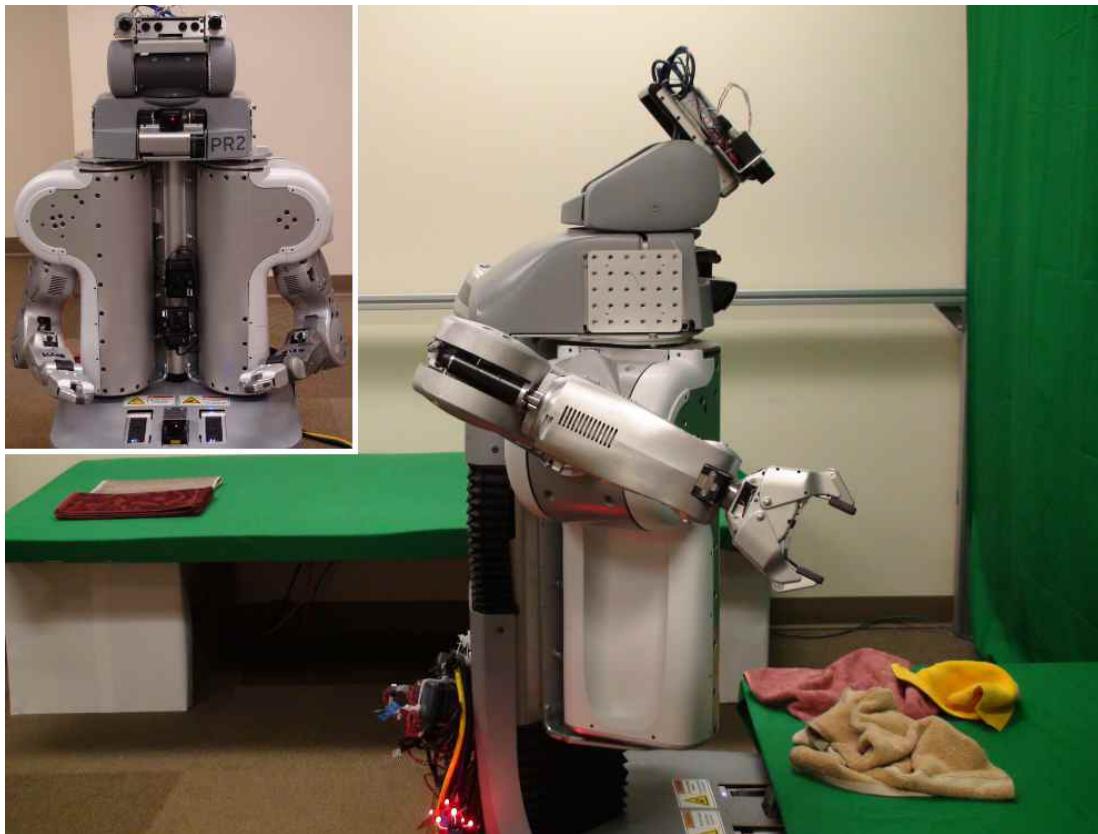


[http://www.popularmechanics.com/technology/robots/  
a15907/best-falls-from-darpa-robot-challenge/](http://www.popularmechanics.com/technology/robots/a15907/best-falls-from-darpa-robot-challenge/)

<https://www.youtube.com/watch?v=g0TaYhjpOfo>

# 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

 Share |  Email |  Print |  Reprint

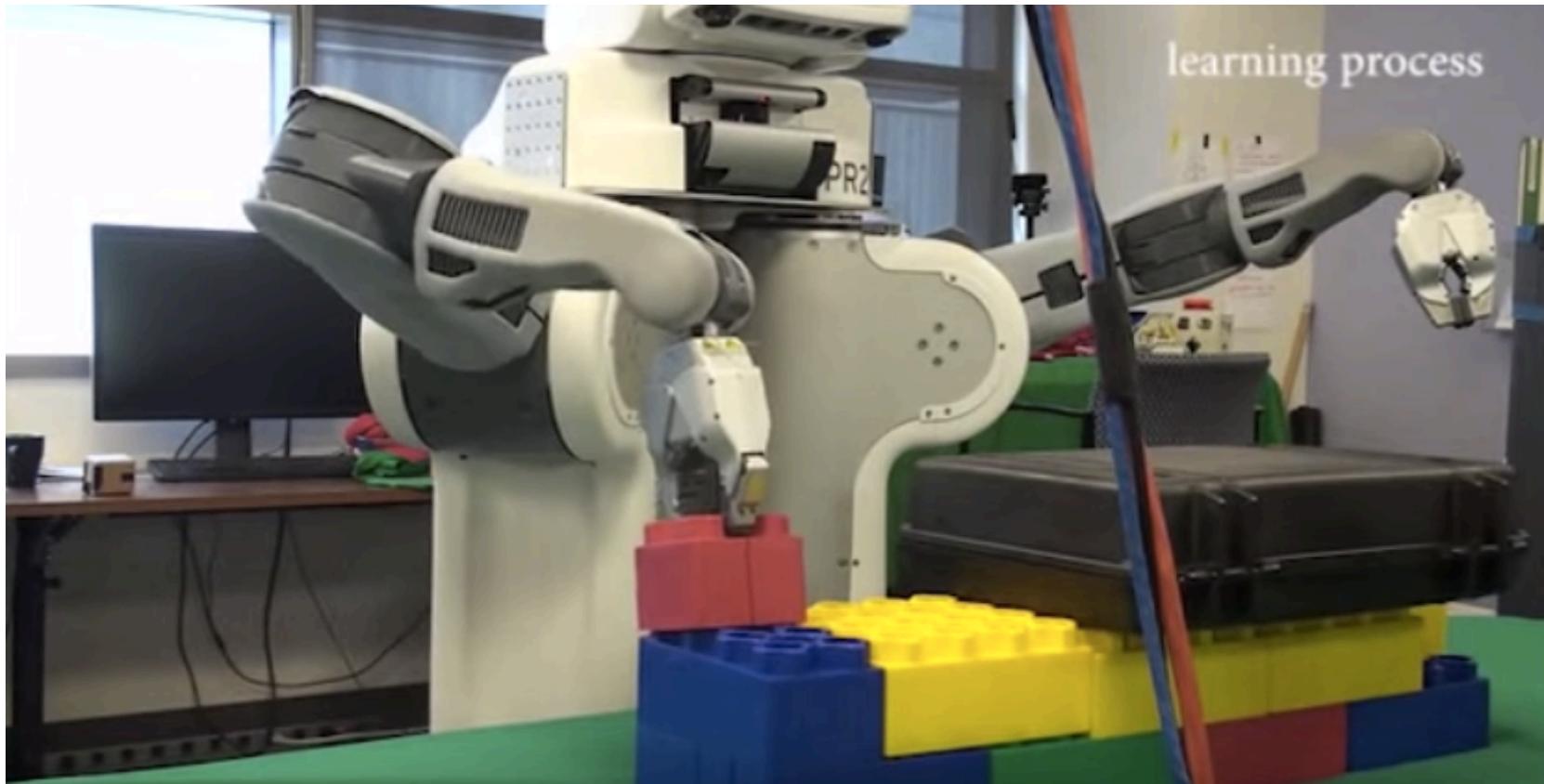


Tom Coburn, a senator from Oklahoma, and PR2, a robot from California.

<http://spectrum.ieee.org/automaton/robotics/robotics-software/us-senator-calls-robot-projects-wasteful>

# Deep sensorimotor learning

---



[YouTube video](#)

S. Levine, C. Finn, T. Darrell and P. Abbeel,  
[End-to-end training of deep visuomotor policies](#), JMLR 2016

# Origins of AI: Early excitement

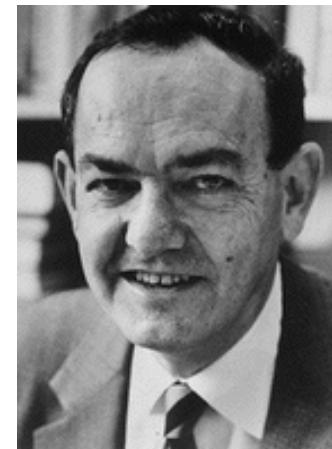
---

- 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**

# Herbert Simon, 1957

---

*"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 embryo—the Weather Bureau's \$2,000,000 "704" computer—learned to differentiate between right and left after fifty attempts in the Navy's demonstration for newsmen.

The service said it would use this principle to build the first of its Perceptron thinking machines that will be able to read and write. It is expected to be finished in about a year at a cost of \$100,000.

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. As do human be-

ings, 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.

# 1958 New York Times...

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."

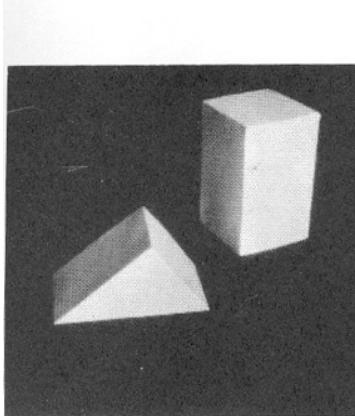
The first Perceptron will have about 1,000 electronic "association cells" receiving electrical impulses from an eye-like scanning device with 400 photo-cells. The human brain has 10,000,000,000 responsive cells, including 100,000,000 connections with the eyes.

# Harder than originally thought

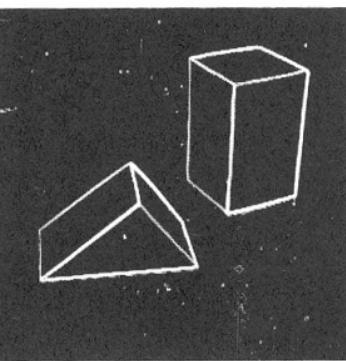
---

- 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.](#)”

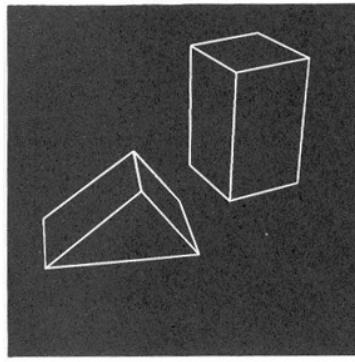
# Blocks world (1960s – 1970s)



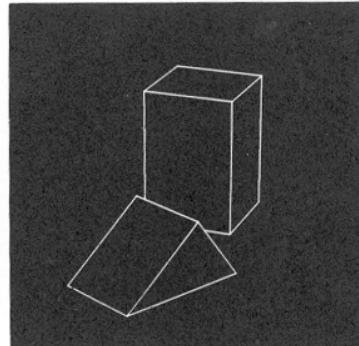
(a) Original picture.



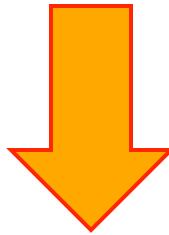
(b) Differentiated picture.



(c) Line drawing.



(d) Rotated view.



???

[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 " <a href="#">AI Winter</a> "

\*[A sociological study of the official history of the perceptrons controversy](#)

# History of AI to the present day

---

1980s	Expert systems boom
Late 1980s-	Expert system bust; the second “AI winter”
Early 1990s	
Mid-1980s	Neural networks and back-propagation
Late 1980s	Probabilistic reasoning on the ascent
1990s-Present	Machine learning everywhere Big Data Deep Learning New industry boom

[History of AI on Wikipedia](#)

[Building Smarter Machines: NY Times Timeline](#)

# Machine Intelligence LANDSCAPE

## CORE TECHNOLOGIES

ARTIFICIAL INTELLIGENCE	DEEP LEARNING	MACHINE LEARNING	NLP PLATFORMS	PREDICTIVE APIs	IMAGE RECOGNITION	SPEECH RECOGNITION							
IBM WATSON Numenta Cycorp Research Reactor SCALED INFERENCE	MetaMind ai-one® Microsoft Research nara	facebook Google SKY MIND	Vision Factory Batch IDL ersatz SignalSense	rapidminer Oxdata H2O Liftgarter Azure ML	context DATA RPM SENSE	cortical.io idibon LUMINOSO Maluuba	wit.ai	AlchemyAPI™ Google ALGORITHMIA	MINDOPS bigml Expect Labs	clarifai MADBTS DNNresearch	lookflow	VISENZE	GRIDSPACE popUP archive NUANCE

## RETHINKING ENTERPRISE

SALES	SECURITY / AUTHENTICATION	FRAUD DETECTION	HR / RECRUITING	MARKETING	PERSONAL ASSISTANT	INTELLIGENCE TOOLS				
Preact RelateIO CLARIBRIDGE infer ATTENITY causata	AVISO NGDATA FRAMED	CROSSMATCH EYEVERIFY CYLANCE BITSIGHT bionym	soft science ThreatMetrix Brighterion	SOCURE feedzai VERIFIN	TalentBin entelo predikt Connectifier gild hiQ CONCEPTWORKS	brightfunnel bloomreach CommandIQ AIRPR RADIUS TellApart people pattern Freshplum	Siri Cortana tempo KASISTO VIV	Google now cleversense Rebinlabs fuse machines CLARA LABS	ADATAQ Quid FirstRain	Palantir Digital Reasoning

## RETHINKING INDUSTRIES

ADTECH	AGRICULTURE	EDUCATION	FINANCE	LEGAL	MANUFACTURING	MEDICAL	
METAMARKETS dstillery rocketfuel YieldMo ADBRAIN	BLUE RIVER TerrAvion ceres imaging HONG KONG CORPORATION THE CLIMATE CORPORATION tule XEROVIA	DECLARA COURSERA KNEWTON kidaptive	Bloomberg alphasense Dataminr	FinGenius KENSH minetta brook BINATIX	Lex Machina brightleaf COUNSELYTICS JUDICATA DiligenceEngine	SIGHT MACHINE MICROSCAN OVISYS RADLER IMAGING	Parzival transcriptic ZEPHYR HEALTH Genescient grand round table bina TUTE GENOMICS
OIL AND GAS	MEDIA / CONTENT	CONSUMER FINANCE	PHILANTHROPIES	AUTOMOTIVE	DIAGNOSTICS	RETAIL	
kaggle AYASDI TACHYUS biota Flutura	Outbrain newslt SAILTHRU wavii ARRIA NarrativeScience Prismatic	Affirm irVenture BILL GUARD LendUp LendingClub Kabbage	DataKind thorn	Google Continental GM mobileye CRUISE	enlitic 3SCAN lumia lumiata ENTOPIA	BAY SENSORS PRISM SKYLABS select euclid	

## RETHINKING HUMANS / HCI

AUGMENTED REALITY	GESTURAL COMPUTING	ROBOTICS	EMOTIONAL RECOGNITION	HARDWARE	DATA PREP	DATA COLLECTION	
wearable intelligence APX blippAR META layar	THALMICLABS LEAP eyeSight GestureTek	iRobot jibo ANKI	LIQUID ROBOTICS SoftBank Boston Dynamics iRobot BeyondVERBAL EMOTIENT cogito	NVIDIA Qualcomm TERADEK rigetti	XILINX NERVANA SYSTEMS Artificial Learning	TRIFACTA tamr Alation	Paxata Connate WorkFusion Import io

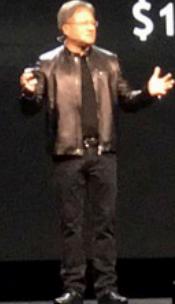


## NVIDIA DGX-1

WORLD'S FIRST  
DEEP LEARNING SUPERCOMPUTER

170TF | "250 servers in-a-box" | [nvidia.com/dgx1](http://nvidia.com/dgx1)

\$129,000



Engadget

<https://www.engadget.com/2016/04/05/nvidia-dgx-1-deep-learning-supercomputer/>

# 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
- 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?

# AI 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.

<http://www.v3.co.uk/v3-uk/news/2419567/ai-weapons-are-a-threat-to-humanity-warn-hawking-musk-and-wozniak>

# Will robots take our jobs? Experts can't decide

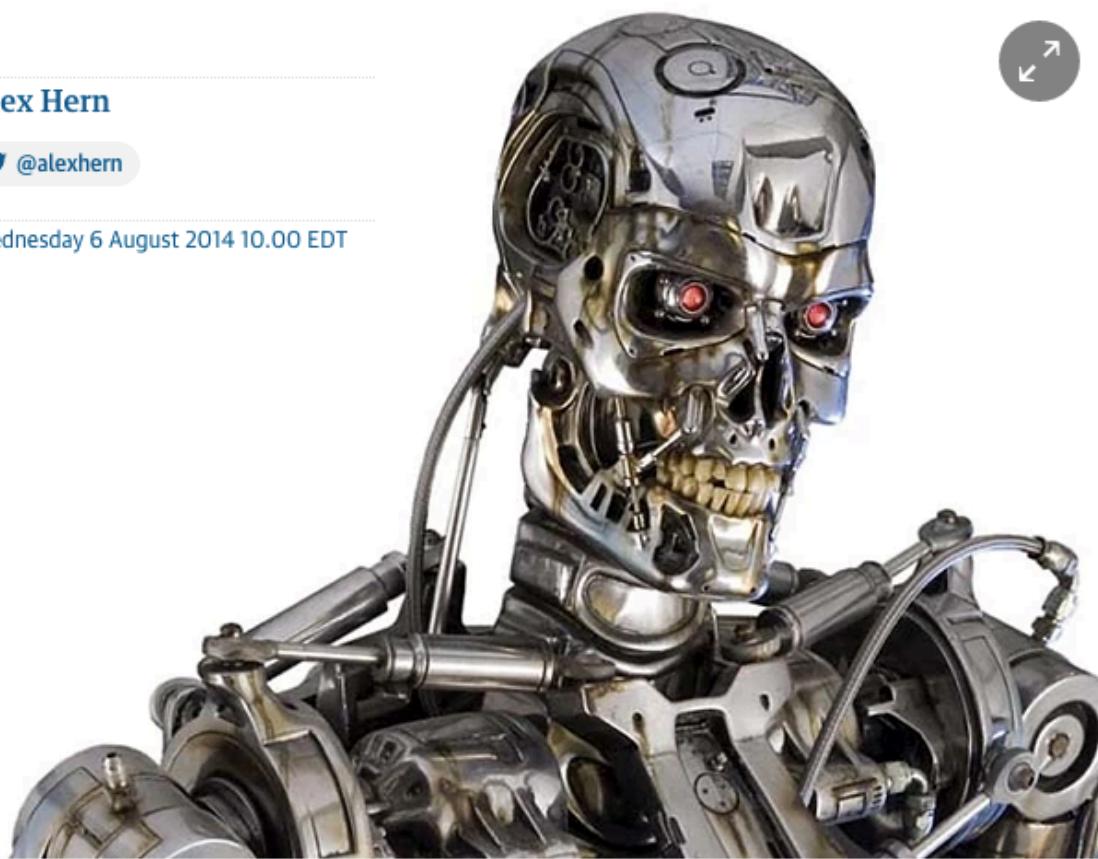
the guardian

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

Alex Hern

 @alexhern

Wednesday 6 August 2014 10.00 EDT



<http://www.theguardian.com/technology/2014/aug/06/robots-jobs-artificial-intelligence-pew>

# 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?
  - More down to earth: [concrete AI safety problems](#)

# 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

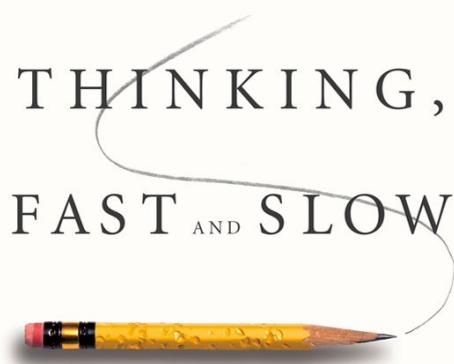
# Two brain systems?

---

- **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

[http://en.wikipedia.org/wiki/Thinking,\\_Fast\\_and\\_Slow](http://en.wikipedia.org/wiki/Thinking,_Fast_and_Slow)

THE NEW YORK TIMES BESTSELLER



DANIEL  
KAHNEMAN

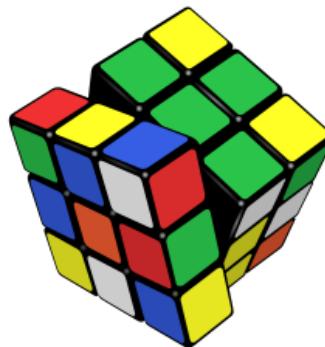
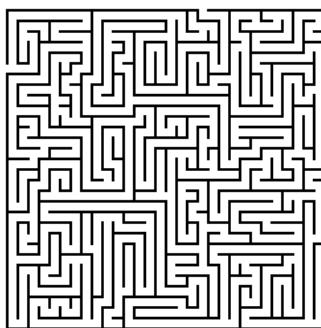
WINNER OF THE NOBEL PRIZE IN ECONOMICS

"[A] masterpiece . . . This is one of the greatest and most engaging collections of insights into the human mind I have read." —WILLIAM EASTERLY, *Financial Times*

# In this class

---

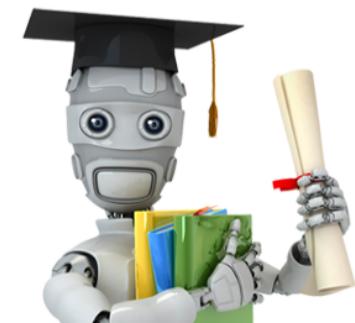
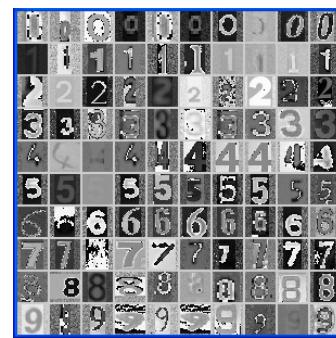
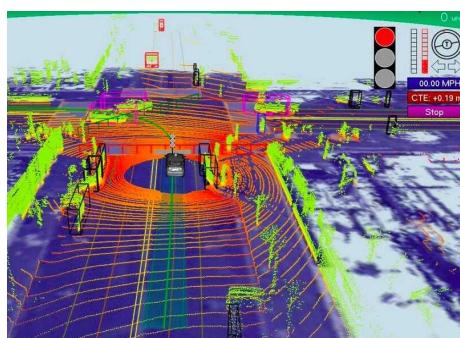
- Part 1: sequential reasoning



8	4	6		7
1			4	
5	9	3	6	5
		7		
4	8	2	1	3
5	2			9
1				
3		9	2	5



- Part 2: pattern recognition and learning



# Philosophy of this class

---

- Goal: use machines to solve hard problems that are traditionally thought to require human intelligence
- We will try to follow a sound scientific/engineering methodology
  - Consider relatively 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