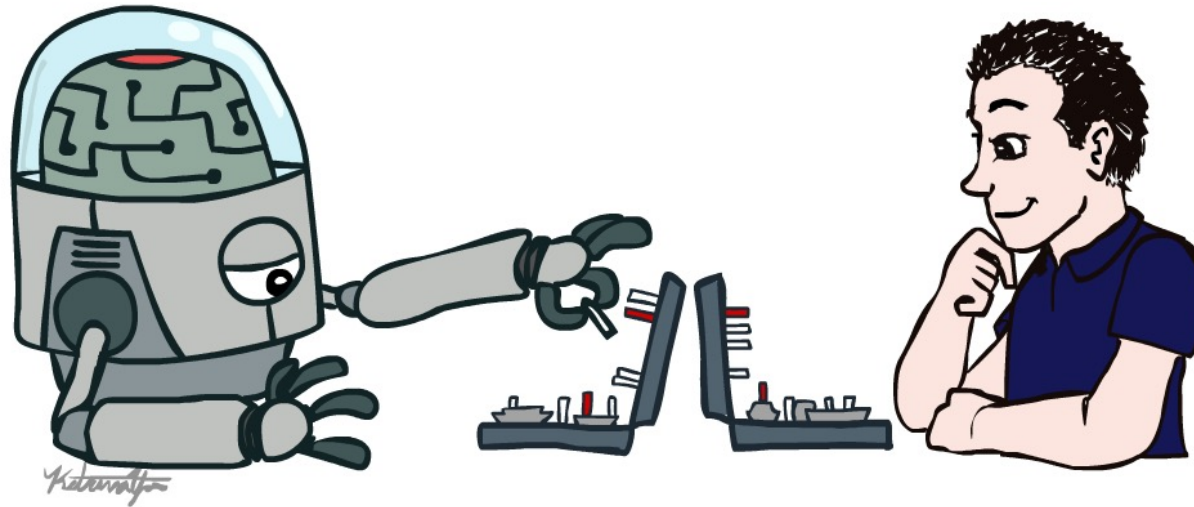


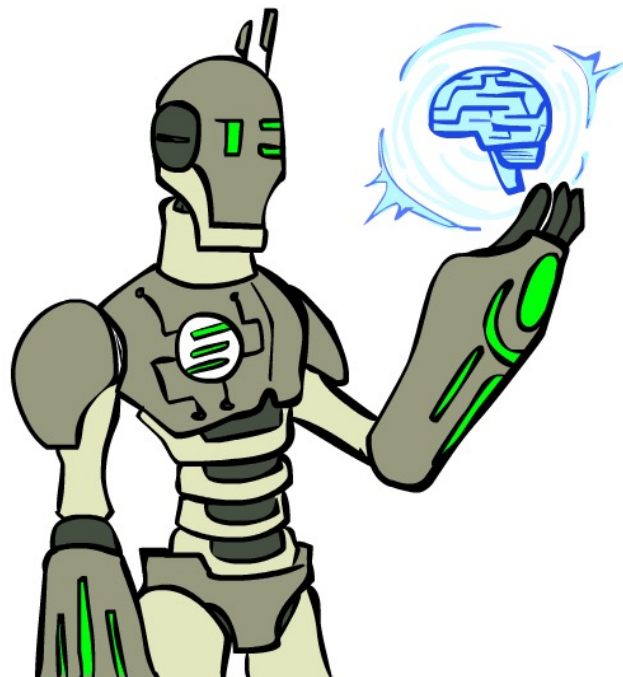
# Artificial Intelligence

## Introduction



# What is AI?

---



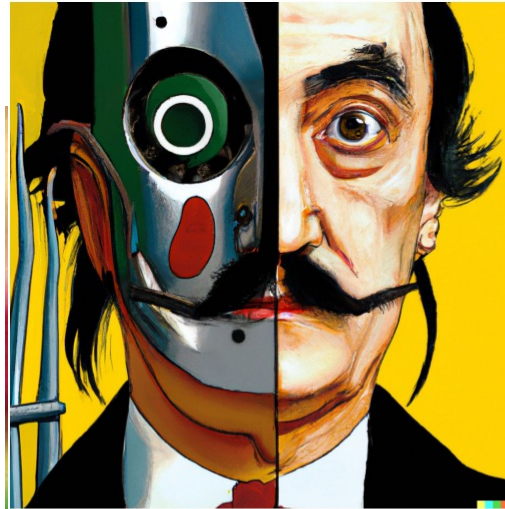
# Current AI hype is having real-world impact

- Public imagination
  - Text assistants



# Current AI hype is having real-world impact

- Public imagination
  - Text assistants
  - Image generation



vibrant portrait painting of Salvador Dalí with a robotic half face



a shiba inu wearing a beret and black turtleneck



a close up of a handpalm with leaves growing from it



an espresso machine that makes coffee from human souls, artstation



panda mad scientist mixing sparkling chemicals, artstation

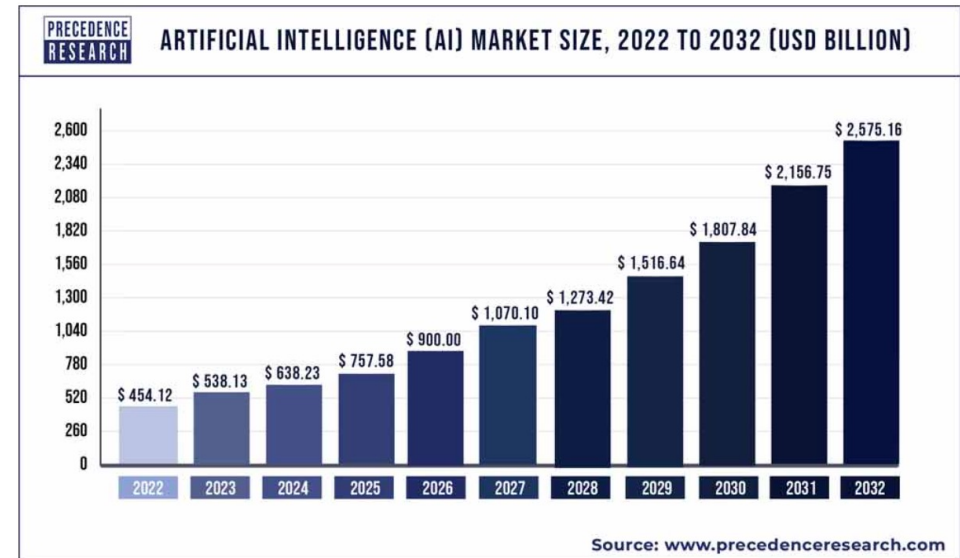


a corgi's head depicted as an explosion of a nebula

# Current AI hype is having real-world impact

- Public imagination
- Economy
  - 454 billion USD globally

The global artificial intelligence (AI) market size was valued at USD 454.12 billion in 2022 and is expected to hit around USD 2,575.16 billion by 2032, progressing with a CAGR of 19% from 2023 to 2032. The North America artificial intelligence market was valued at USD 167.30 billion in 2022.



<https://www.precedenceresearch.com/artificial-intelligence-market>

# Current AI hype is having real-world impact

- Public imagination
- Economy
- Politics



# Current AI hype is having real-world impact

- Public imagination
- Economy
- Politics
- Law

Aug. 18, 2023, 12:18 PM; Updated: Aug. 18, 2023, 12:48 PM

## AI-Generated Art Lacks Copyright Protection, D.C. Court Says (1)



**Riddhi Setty**  
Reporter



**Isaiah Poritz**  
Legal Reporter



Bloomberg Law, 2023

# Current AI hype is having real-world impact

- Public imagination
- Economy
- Politics
- Law
- Labor

Finance & economics | Free exchange

New research shows the robots are coming for jobs—but stealthily

Look beneath the aggregate economic numbers, and change is afoot

The Economist, 2021

## *The Optimist's Guide to Artificial Intelligence and Work*

The focus of much discussion is on how it will replace jobs, but nothing is inevitable.

New York Times, 2023

## **The human labor behind AI chatbots and other smart tools**

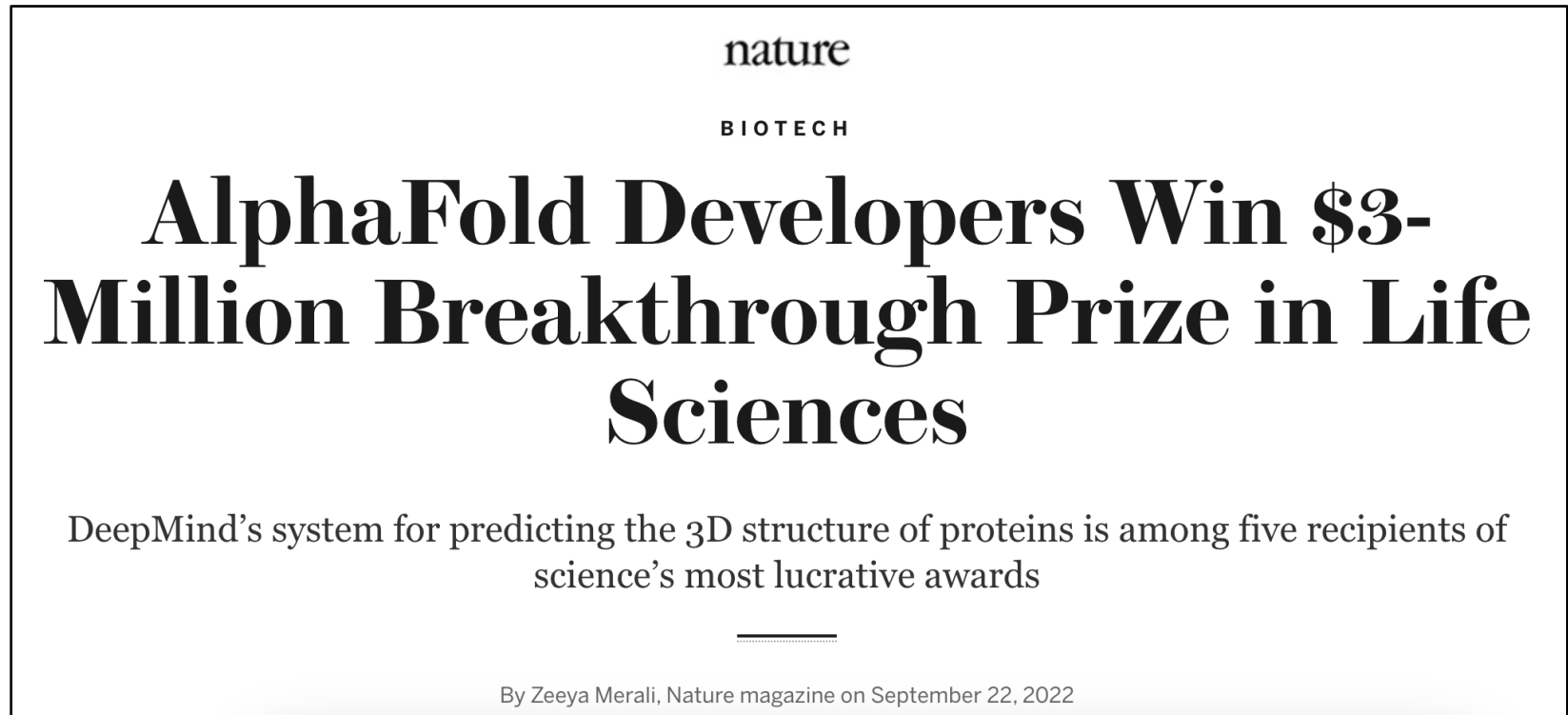
Data labeling is an important step in developing artificial intelligence but also exposes the people doing the work to harmful content.

MarketWatch, 2023



# Current AI hype is having real-world impact

- Public imagination
- Economy
- Politics
- Law
- Labor
- Sciences



Nature, 2022

# Current AI hype is having real-world impact

- Public imagination
- Economy
- Politics
- Law
- Labor
- Sciences
- Education

BREAKING

## ChatGPT In Schools: Here's Where It's Banned—And How It Could Potentially Help Students

**Arianna Johnson** Forbes Staff

*I cover the latest trends in science, tech and healthcare.*

Follow

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Jan 18, 2023, 02:31pm EST

Forbes, 2023

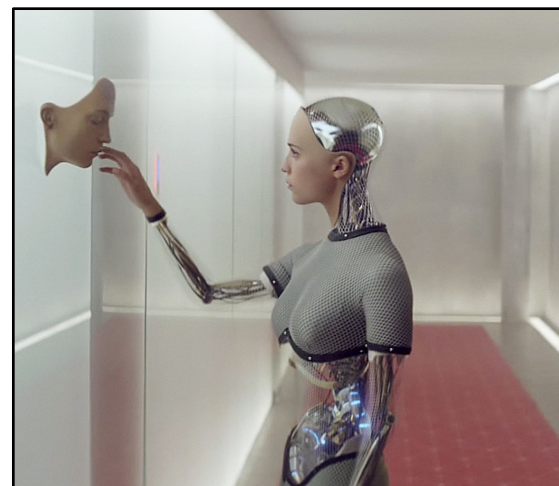
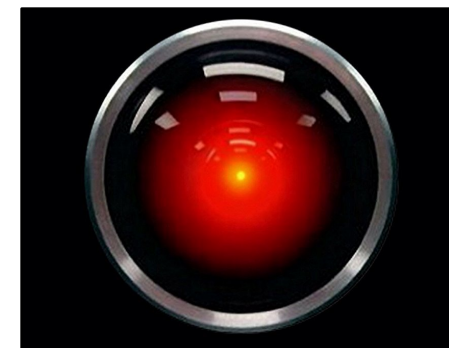
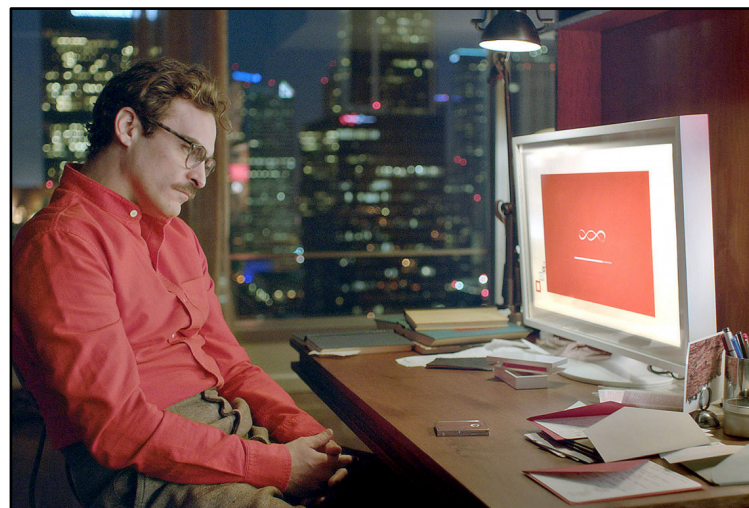
# Current AI hype is having real-world impact

---

- Public imagination
- Economy
- Politics
- Law
- Labor
- Sciences
- Education

Ok, but what actually is AI???

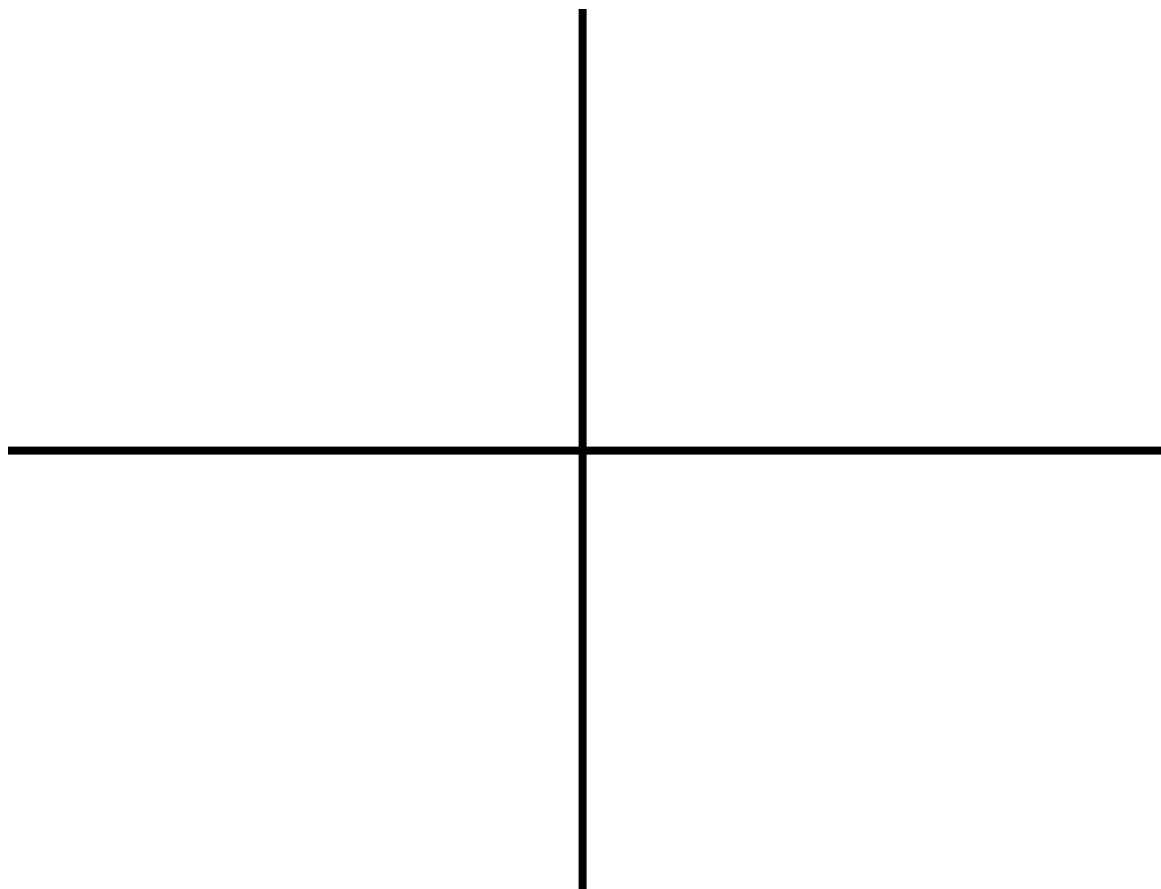
# Science fiction AI?



# Goal: what should we build?

---

Should we make machines that...



# Goal: what should we build?

---

- **Scientific goal:** to understand the principles that make intelligent behavior possible in natural or artificial systems.
  - analyze natural and artificial agents
  - formulate and test hypotheses about what it takes to construct intelligent agents
  - design, build, and experiment with computational systems that perform tasks that require intelligence
- **Engineering goal:** design useful, intelligent artifacts.
- Analogy between studying flying machines and thinking machines.

# What is Artificial Intelligence?

---

- Some definitions that have been proposed
  1. Systems that think like humans
  2. Systems that act like humans
  3. Systems that think rationally
  4. Systems that act rationally

# Thinking Like Humans

---

Model the cognitive functions and behaviors of humans

- Human beings are our best example of intelligence
- We should use that example!



# What is Artificial Intelligence?

---

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  4. Systems that act rationally

# Acting Like Humans

---

- Turing test (1950)
  - operational definition of intelligent behavior
  - Can a human interrogator tell whether (written) responses to her (written) questions come from a human or a machine?
- No system has yet passed the test
  - Yearly competition: <http://www.loebner.net/Prizef/loebner-prize.html>
  - Can play with best entry from 2008: Chatbot Elbot ([www.elbot.com](http://www.elbot.com))
- Is acting like humans really what we want?
  - Humans often think/act in ways we don't consider intelligent
  - Why?

# What is Artificial Intelligence?

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- Some definitions that have been proposed
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  4. Systems that act rationally

# Thinking Rationally

---

- Rationality: an **abstract ideal of intelligence**, rather than “whatever humans think/do”
  - Ancient Greeks invented **sylogisms**: argument structures that always **yield correct conclusions given correct premises**
  - This led to **logic**, and **probabilistic reasoning**
- Is rational thought enough?
  - A system that only thinks and doesn't do anything is quite useless
  - Any means of communication would already be an **action**
  - And it is hard to measure thought in the first place ...

# Acting Rationally

---

## We will emphasize this view of AI

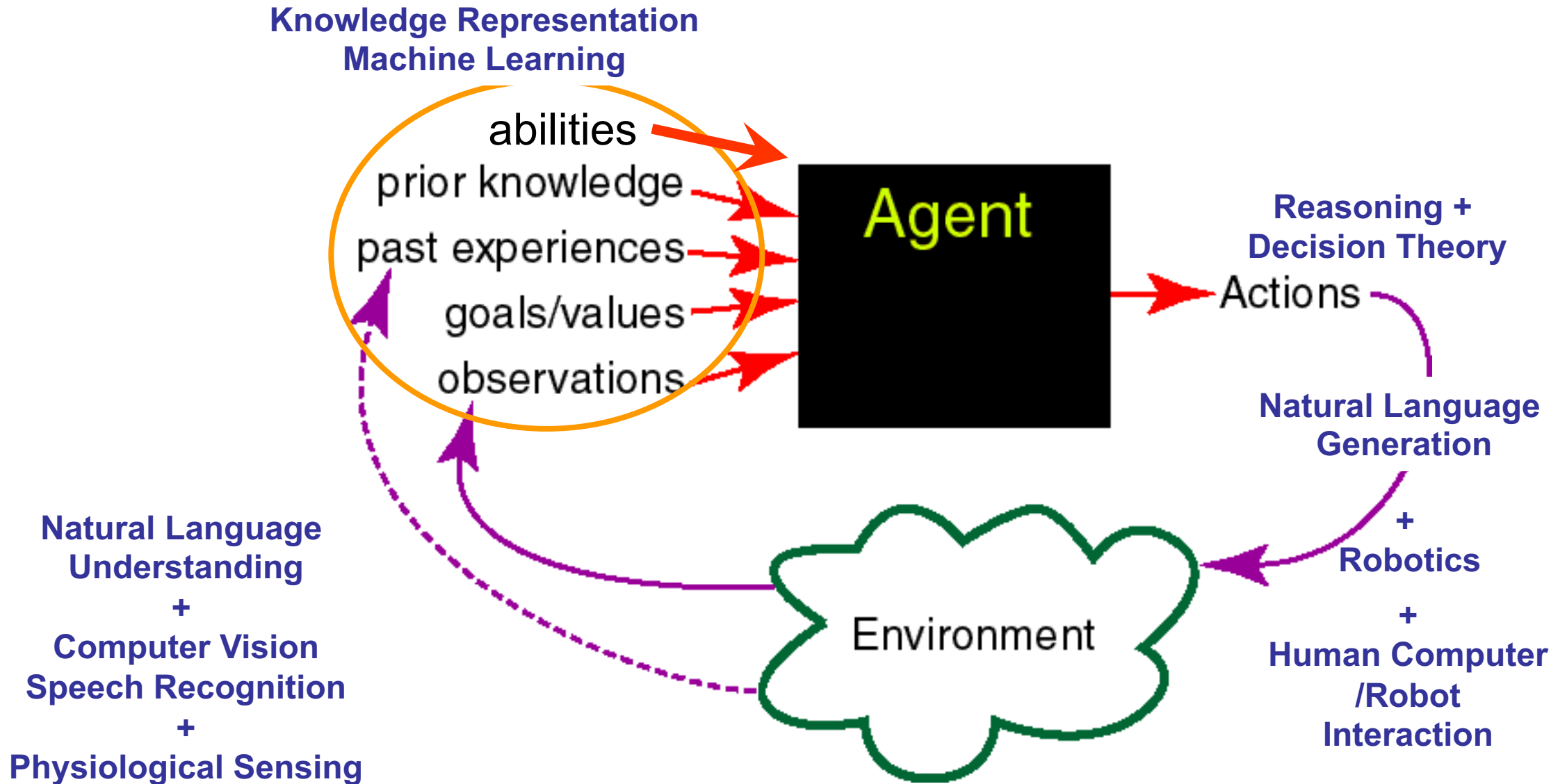
- Rationality is **more cleanly defined** than human behaviour, so
  - it's a better design objective
  - in cases where human behaviour is not rational, often we'd prefer rationality
    - Example: you wouldn't want a shopping agent to make impulsive purchases!
  - And once we have a rational agent, we can always tweak it to make it irrational!
- It's easier to define rational action than rational thought

# AI as Study and Design of Intelligent Agents

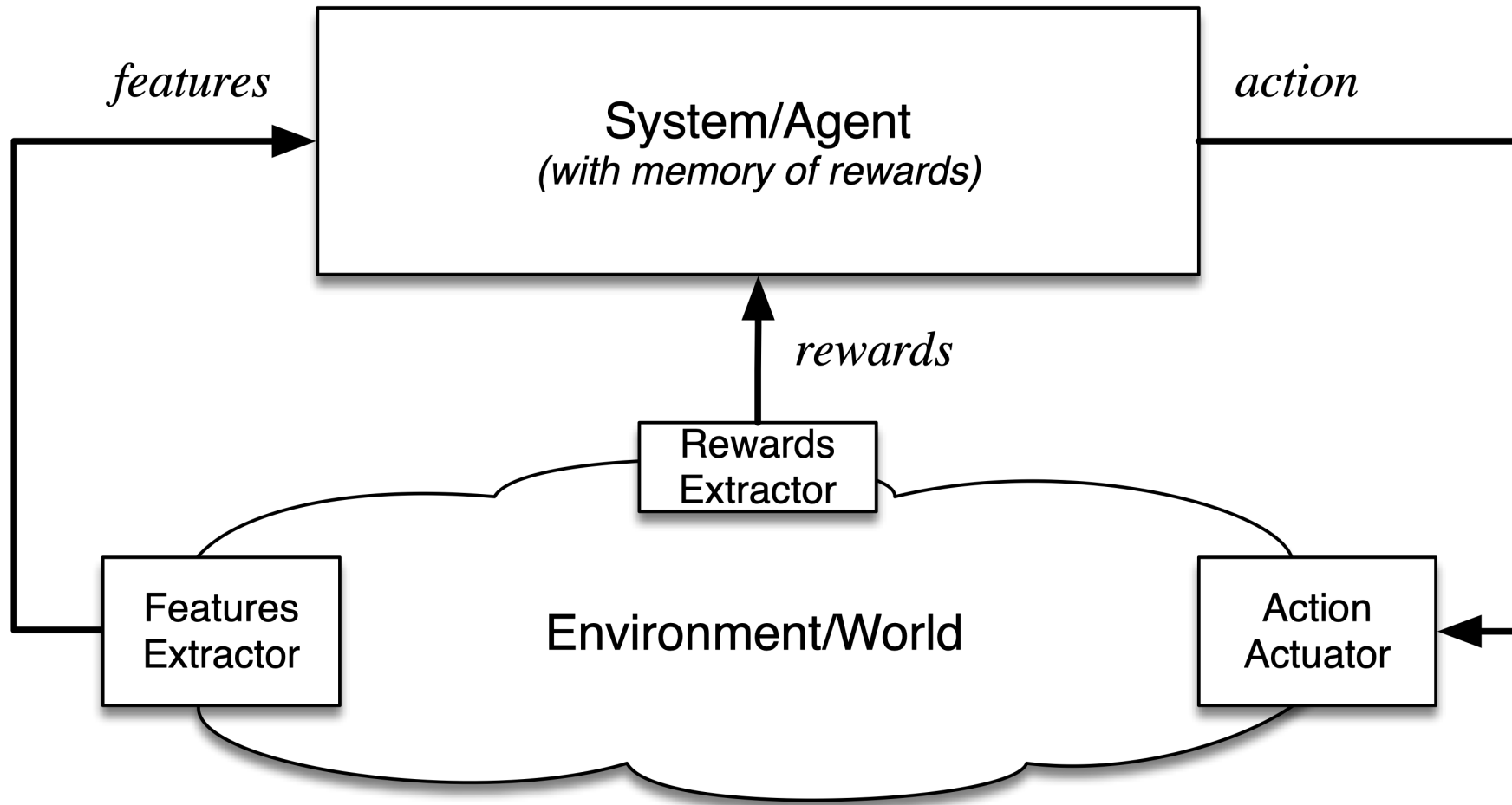
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- **Intelligent agents**: artifacts that **act rationally** in their environment
  - Their **actions** are **appropriate** for their goals and circumstances
  - They are **flexible** to changing environments and goals
  - They **learn** from experience
  - They make **appropriate choices** given **perceptual limitations** and **limited resources**
- This definition drops the constraint of *cognitive plausibility*
  - Same as building flying machines by understanding general principles of flying (aerodynamic) vs. by reproducing how birds fly

# Intelligent Agents in the World



# Reinforcement Learning





# Computational Agents

---

- A computational agent is an agent whose decisions about its actions can be explained in terms of computation.
- The decisions can be broken down into primitive operations that can be implemented in a physical device.

# Robots vs. Other Intelligent Agents

---

- In AI, artificial agents that have a physical presence in the world are known as **robots**
  - Robotics is the field concerned with the implementation of the physical aspects of a robot
    - I.e., perception of and action in the physical environment
    - Sensors and actuators
- Agents without a physical presence: **software agents**
  - E.g. desktop assistants, decision support systems, web crawlers, text-based translation systems, intelligent tutoring systems, etc
  - They also interact with an environment, but not the physical world
- **Software agents and robots**
  - differ in their interaction with the environment
  - share all other fundamental components of intelligent behavior

# Examples of Agents

---

- **Organizations** Microsoft, European Union, Real Madrid FC, an ant colony,...
- **People** teacher, physician, stock trader, engineer, researcher, travel agent, farmer, waiter...
- **Computers/devices** thermostat, user interface, airplane controller, network controller, game, advising system, tutoring system, diagnostic assistant, robot, Google car, Mars rover...
- **Animals** dog, mouse, bird, insect, worm, bacterium, bacteria...
- book(?), sentence(?), word (?), letter(?)  
Can a book or article do things?  
Convince? Argue? Inspire? Cause people to act differently?

# Inputs to an Agent

---

- **Abilities** — the set of possible actions it can perform
- **Goals/Preferences** — what it wants, its desires, its values,...
- **Prior Knowledge** — what it comes into being knowing, what it doesn't get from experience,..
- **History** of stimuli
- (current) **stimuli** — what it receives from environment now (observations, percepts)
- **past experiences** — what it has received in the past

# Example agent: autonomous car

---

- **abilities**: steer, accelerate, brake
- **goals/ preferences** safety, get to destination, timeliness ... prior knowledge: street maps, what signs mean, what to stop for ...
- **stimuli**: vision, laser, GPS, voice commands ...
- **past experiences**: how braking and steering affects direction and speed...

# Example agent: teacher

---

- **abilities**: present new concept, drill, give test, explain concept,...
- **goals/preferences** particular knowledge, skills, inquisitiveness,
- **social skills**,...
- **prior knowledge**: subject material, teaching strategies,...
- **stimuli**: test results, facial expressions, errors, focus,...
- **past experiences**: prior test results, effects of teaching strategies,  
...

# Example agent: thermostat for heater

---

- **abilities**: turn heater on or off
- **goals/ preferences** conformable temperature, save fuel, save money
- **prior knowledge**: 24 hour cycle, weekends
- **stimuli**: temperature, set temperature, who is home, outside temperature
- **past experiences**: when people come and go, who likes what temperature

# Example agent: medical doctor

---

- abilities:
- goals/preferences:
- prior knowledge:
- stimuli:
- past experiences:



# Other example Agents

---

- Google Maps
- Logistics planner
- Bee
- Smart Home
- ...

# What About the Brain?

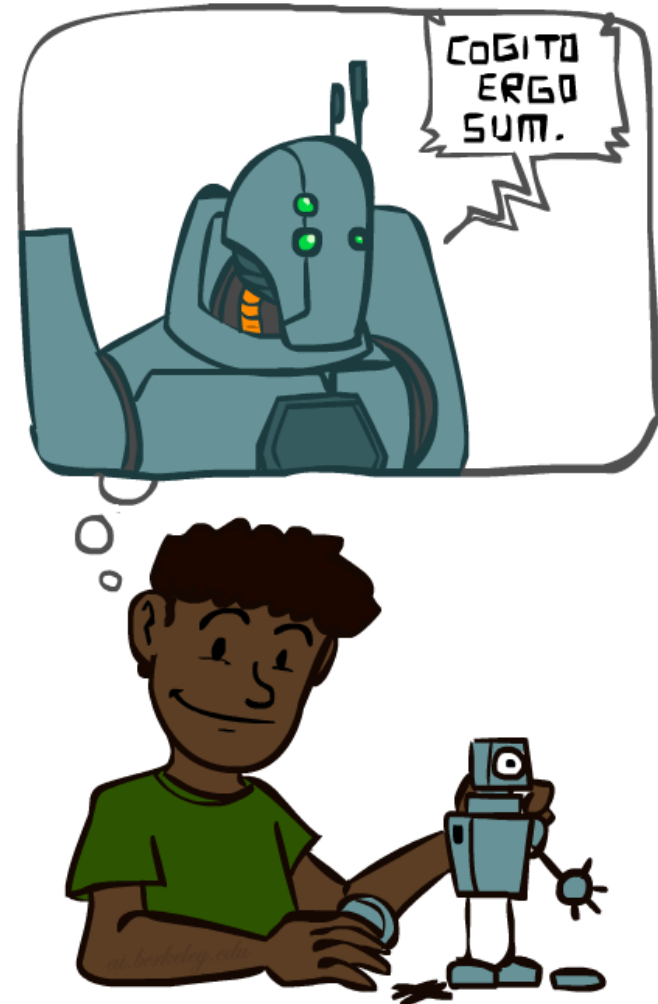
- Brains (human minds) are very good at making rational decisions, but not perfect
- Brains aren't as modular as software, so hard to reverse engineer!
- AI may be better than brains at some tasks
- *“Brains are to intelligence as wings are to flight”*
- We can't yet build AI on the scale of the brain
  - ~100T synapses in the human brain vs ~1.8T weights in GPT4
- Still, the brain can be a great inspiration for AI!



# A (Short) History of AI

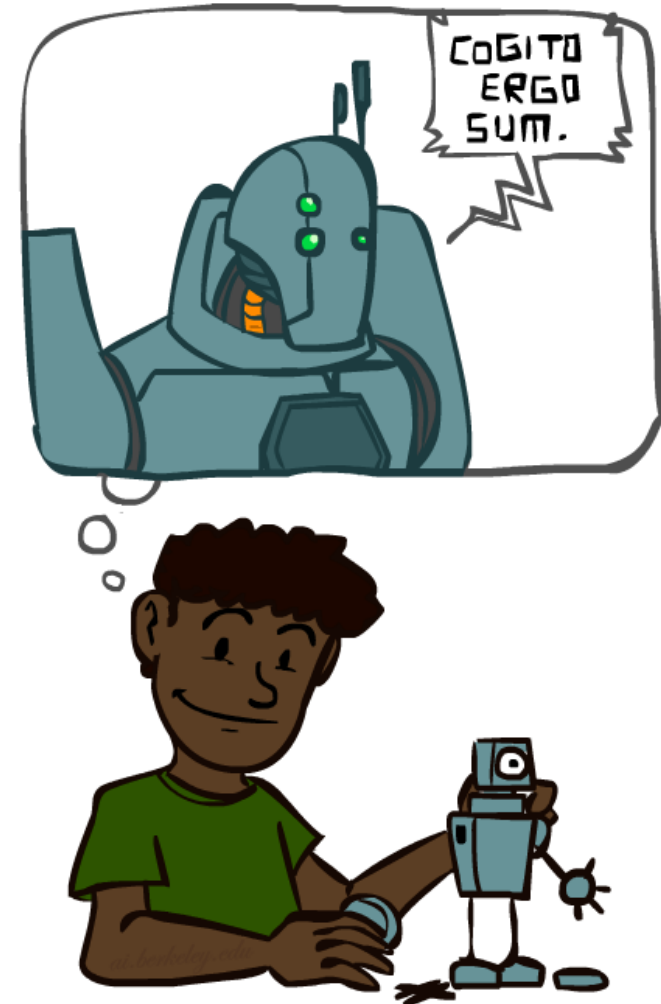
- 1940-1950: Early days: neural and computer science meet
  - 1943: McCulloch & Pitts: Perceptron–boolean circuit model of brain
  - 1950: Turing's “Computing Machinery and Intelligence”
- 1950—70: Excitement! Logic-driven
  - 1950s: Early AI programs, including Samuel's checkers program, Newell & Simon's Logic Theorist, Gelernter's Geometry Engine
  - 1956: Dartmouth meeting: “Artificial Intelligence” adopted

*“We propose that a **2-month, 10-man study of artificial intelligence** be carried out **during the summer of 1956** at Dartmouth College in Hanover, New Hampshire. The study is to proceed on the basis of the conjecture that **every aspect of learning** or **any other feature of intelligence** can in principle be so precisely described that a machine can be made to simulate it. An attempt will be made to find how to make machines use language, form abstractions and concepts, solve kinds of problems now reserved for humans, and improve themselves. **We think that a significant advance can be made** in one or more of these problems if a carefully selected group of scientists work on it together for a summer.”*



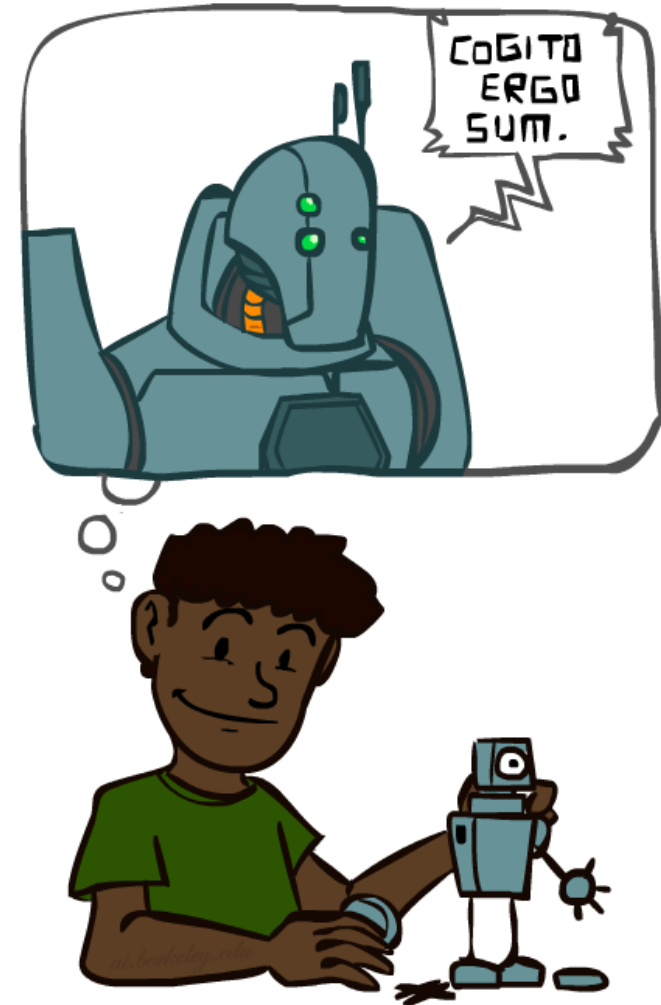
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  - 1956: Dartmouth meeting: “Artificial Intelligence” adopted
  - 1969: Minsky & Papert: perceptrons can't learn XOR/parity!
- **1970—90: Knowledge-based approaches**
  - 1969—79: Early development of knowledge-based systems
  - 1980—88: Expert systems industry booms; backpropagation makes it feasible to train multi-layer neural networks
  - 1988—93: Expert systems industry busts: “AI Winter”
- **1990—2010: Statistical approaches, agents**
  - Resurgence of probability, focus on uncertainty
  - Agents and learning systems... “AI Spring”?
  - 1992: TD-Gammon achieves human-level play at backgammon
  - 1997: Deep Blue defeats Gary Kasparov at chess
  - 2002: Embodied AI; Roomba vacuum invented



# A (Short) History of AI

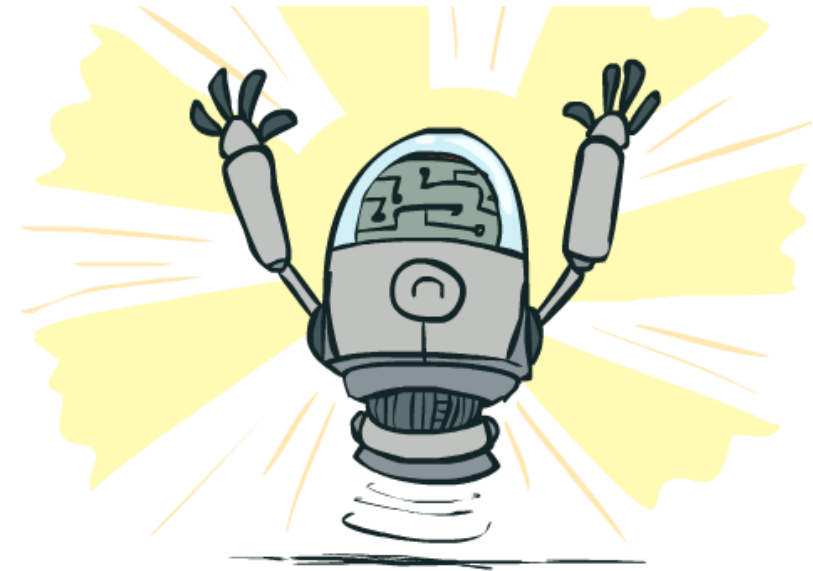
- **2010—2017: Big Data, GPUs, Deep Learning**
  - 2011: Apple releases Siri
  - 2012: AlexNet wins ImageNet competition
  - 2015: DeepMind achieves “human-level” control in Atari games
  - 2016: DeepMind’s AlphaGo defeats Lee Sedol at Go
  - 2016: Google Translate migrates to neural networks
- **2017—: Scaling Up, Large Language Models**
  - 2017: Google invents Transformer architecture
  - 2017: DeepStack/Libratus defeat humans at poker
  - 2018-2020: AlphaFold predicts protein structure from amino acids
  - 2021-2022: Modern text-to-image generation
  - 2022: OpenAI releases ChatGPT
  - 2023: Every other company also releases a chatbot



# What Can AI Do?

**Quiz:** Which of the following can be done at present?

- ✓ Win against any human at chess?
- ✓ Win against the best humans at Go?
- Play a decent game of table tennis?
- Unload any dishwasher in any home?
- Drive safely along the highway?
- Drive safely along streets of San Francisco?
- Buy a week's worth of groceries on the web?
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- Discover and prove a new mathematical theorem?
- Perform a surgical operation?
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- Write an intentionally funny story?
- Construct a building?



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Google's AlphaGo beats Lee Sedol at Go in 2016



But ... a plot twist in 2023!

*DEEP BLUE WAS JUST THE START —*

## Man beats machine at Go in human victory over AI

Amateur exploited weakness in systems that have otherwise dominated grandmasters.

RICHARD WATERS, FINANCIAL TIMES - 2/19/2023, 4:51 AM

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## California just opened the floodgates for self-driving cars

After a state regulatory board ruling, San Francisco will have 24/7 robotaxis on its streets. A Washington Post analysis shows how it's a pivotal moment for the industry.

By [Trisha Thadani](#) and [Jeremy B. Merrill](#)

Updated August 10, 2023 at 10:06 p.m. EDT | Published August 10, 2023 at 9:15 p.m. EDT

**The Register**

## California DMV hits brakes on Cruise's SF driverless fleet after series of fender benders

50% chop effective 'immediately' as department investigates traffic and safety issues

[Jude Karabus](#)

Mon 21 Aug 2023 | 14:28 UTC

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- ? Write an intentionally funny story?
- Construct a building?



**You**

Please write me a very funny, and extremely short story.

< 6 / 6 >



**ChatGPT**

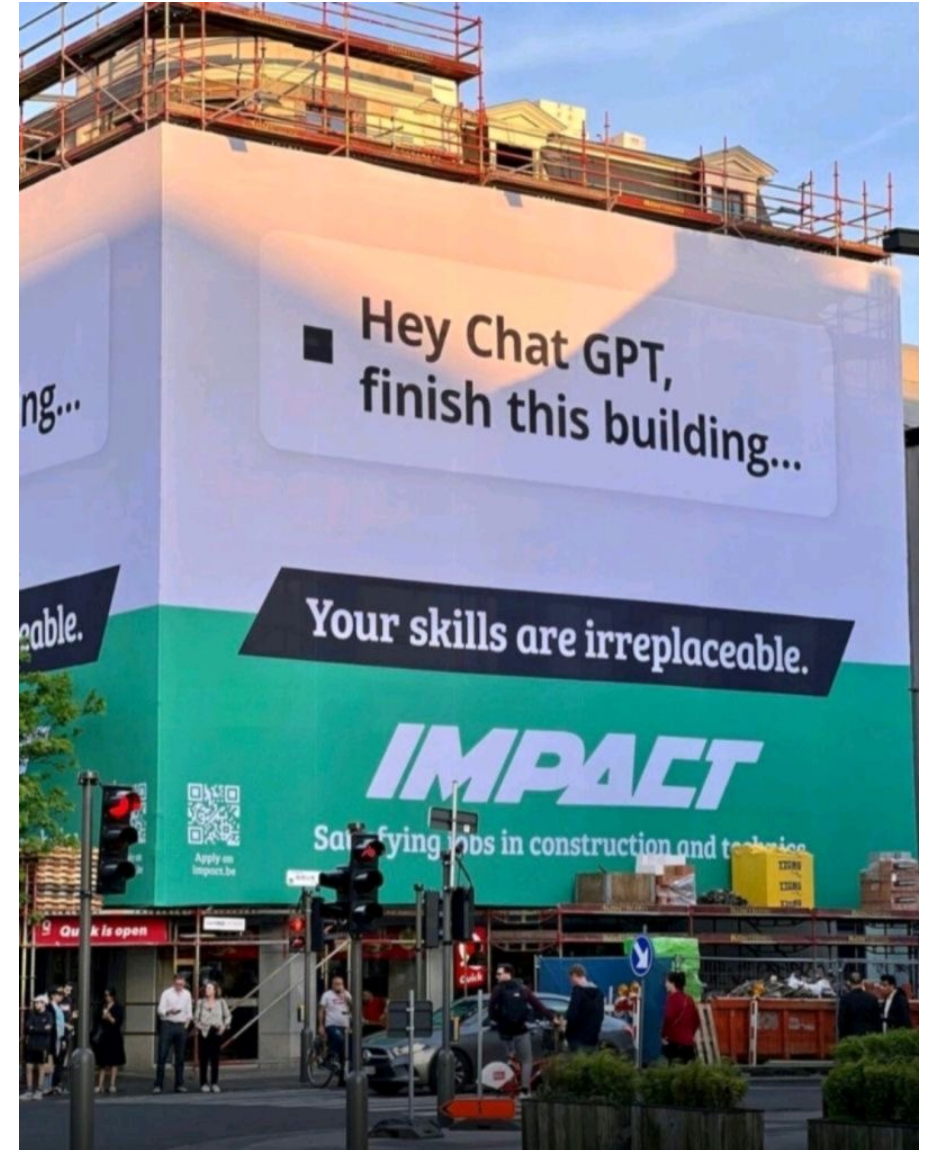
Once there was a chicken who was terribly afraid of crossing roads. One day, it mustered up all its courage, stepped onto the road, and halfway across, it suddenly stopped and said, "Wait, why am I doing this again?"

< 12 / 12 >    

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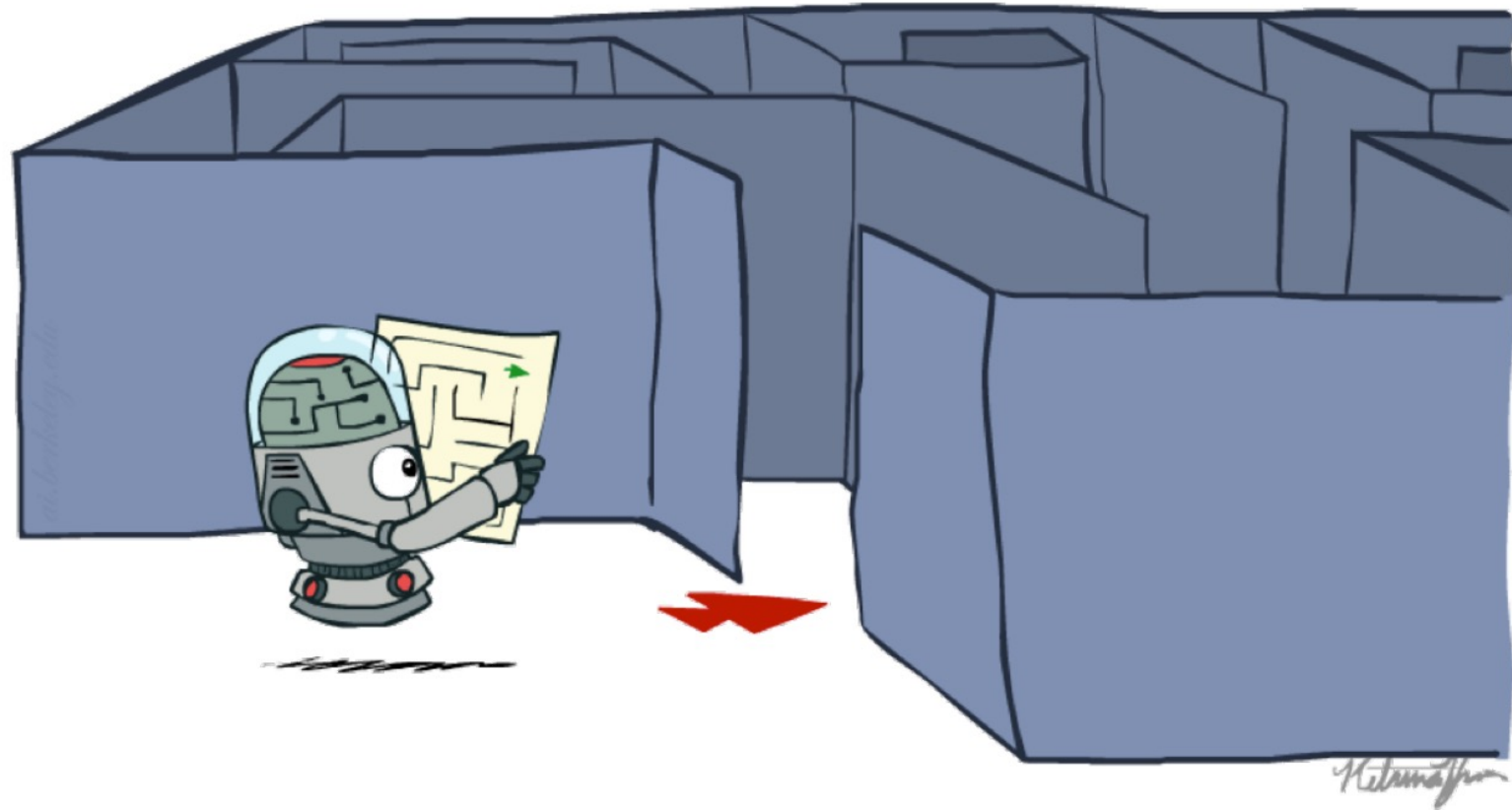


# YES, but what is AI, technically?

---

- **Classical programming:**
  - Input + Program → Results
- **Artificial Intelligence:**
  - Data + Knowledge + Goal → Program

# How do we implement all this: Search



# Search

---

Changing random stuff  
until your program works is  
"hacky" and "bad coding practice".

But if you do it fast enough it is  
"Artificial Intelligence"  
and pays 4x your current salary.

# Rational Agents blocks

---

Core Components of Rational Agents:

Search &  
Planning

Probability &  
Inference

Supervised  
Learning

Reinforcement  
Learning



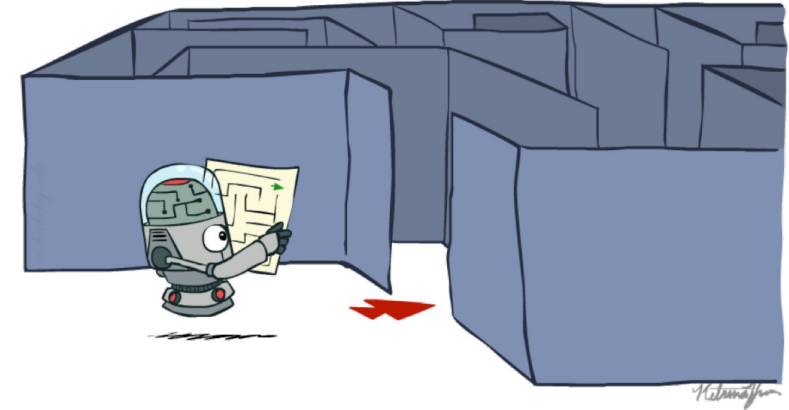
# Rational Agents blocks

Search &  
Planning

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Inference

Supervised  
Learning

Reinforcement  
Learning



How can I use my *model* of the world to find a *sequence of actions* to achieve my *goal*?

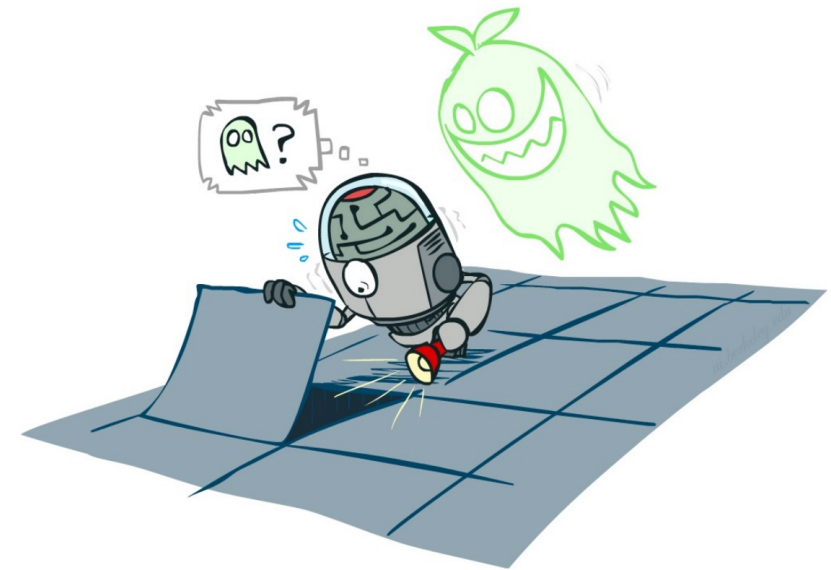
# Rational Agents blocks

Search &  
Planning

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How can I make sense of *uncertainty*?

# Rational Agents blocks

Search &  
Planning

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Inference

Supervised  
Learning

Reinforcement  
Learning



How can I learn a ***model*** of the world from ***data***?

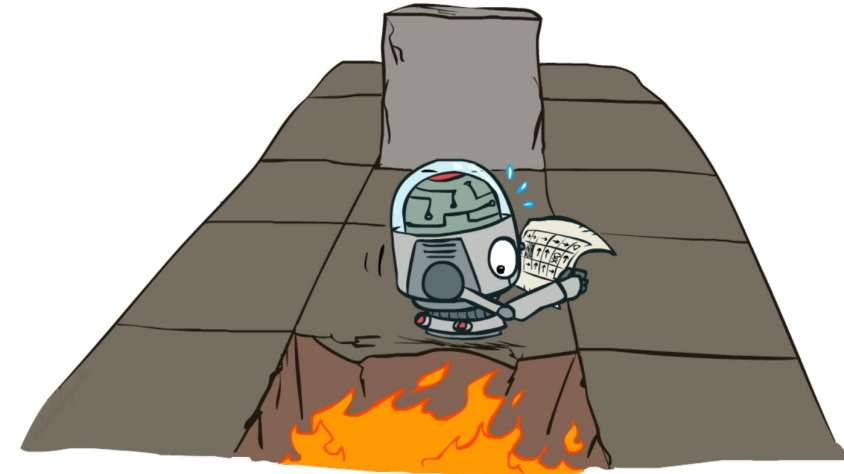
# Rational Agents blocks

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Inference

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How can I learn a ***policy*** for any situation so that I can ***maximize utility***?

# References

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- Main book:

- David Poole and Alan Mackworth,  
Artificial Intelligence: Foundations of Computational Agents, 3e  
Cambridge University Press, 2023  
Fully available online at: <https://artint.info>

- Additional reference:

- Stuart Jonathan Russell and Peter Norvig,  
Artificial Intelligence: A Modern Approach, 4e  
Prentice Hall, 2020