

CS181: Artificial Intelligence

Introduction

Kan Ren

Fall 2024

Outlines

- Administrative stuff
- A brief introduction to AI
- Course content overview

ADMINISTRATIVE STUFF

Administrative stuff

- Instructor: Kan Ren
 - Email: renkan@shanghaitech.edu.cn
 - Office: SIST 1C-303A
- First-year assistant professor at VDI, SIST
 - Machine learning for perception, cognition, and decision making upon multi-modal big data, e.g., foundation model research and AI agents.
 - How to conduct foundation models on more modalities, e.g., time series data?
 - Explore and understand the underlying mechanisms of large models.
 - Improve reasoning and decision making of large models in real-world scenarios.
 - Previous Senior Researcher at Microsoft Research Asia.



Administrative stuff

- TAs
 - Our talented staff team!



吴昊一



张峥



李昌明



顾书齐

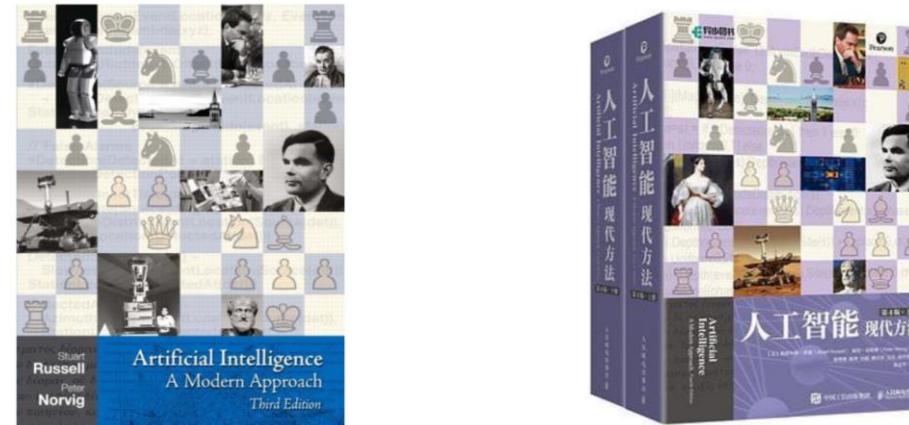
Administrative stuff

- Classes
 - Wed/Fri 10:15 – 11:55am @教学中心303
 - 16 weeks
 - Language: Written materials in English, lectures in Chinese
- Office hour
 - TBA

Administrative stuff

■ Main textbook

- [AIMA] Artificial Intelligence: A Modern Approach, Stuart Russell and Peter Norvig, 4th edition, 2020.
- [中译版] 人工智能：现代方法（第4版）, 2022



- Additional reference books will also be used

Administrative stuff

- Blackboard
 - Announcements, homework assignments, slides, etc.
- Piazza
 - Discussion and QA
 - <https://piazza.com/shanghaitech.edu.cn/fall2024/cs181>
- AutoLab
 - Programming assignments
- GradeScope
 - Exam grading

Administrative stuff

- **Grading**
 - 6 homework assignments (10%)
 - 6 programming assignments (25%)
 - Project (15%): 2nd half of the semester
 - Midterm exam (25%): around mid Nov.
 - Final exam (25%): in week 17-18
- **You have 5 slip days to use across the semester**

Administrative stuff

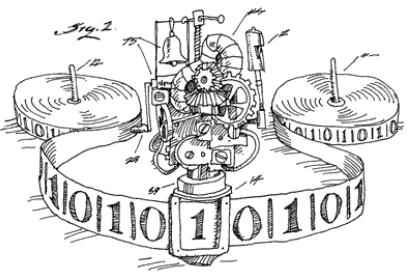
- **Plagiarism**
 - All assignments must be done individually
 - You may not look at solutions from any other source
 - You may not share solutions with any other students
 - Plagiarism detection software will be used on all the programming assignments
 - Way of collaboration
 - You may discuss together or help another student debug code
 - However, you cannot dictate or give the exact solution

Administrative stuff

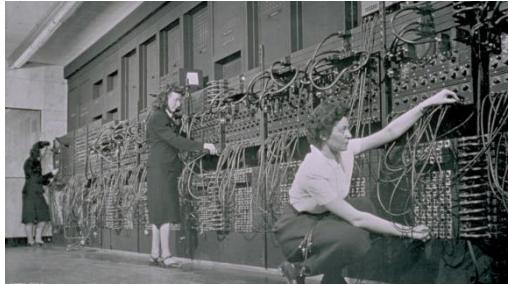
- Plagiarism punishment
 - When one student copies from another student, both students are responsible
 - Zero point on the assignment or exam in question
 - Repeated violation will result in an F grade for this course as well as further discipline at the school/university level

A BRIEF INTRODUCTION TO AI

History of Computer Science ~ 2000



1936/图灵
提出图灵机
计算机的理论模型

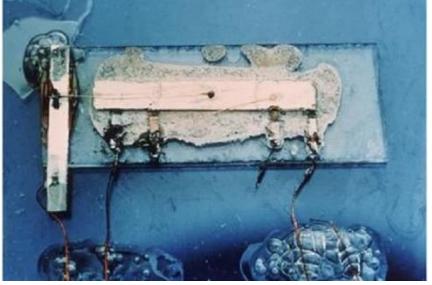


1945/宾大 电子数值积分计算机 世界上第一台通用计算机



1947/Bell 世界上第一个晶体管 (CPU的核心部件)

AI 诞生 (John McCarthy) /1956 ←



```
  *> setup the identification division
  IDENTIFICATION DIVISION.
  *> setup the program id
  PROGRAM-ID. HELLO.
  *> setup the procedure division (lik
  PROCEDURE DIVISION.
    *> print a string
    DISPLAY 'WILLKOMMEN'.
  *> end our program
  STOP RUN.
```

1953/IBM
COBOL语言
第一个编程语言



1958/Jack Kilby
发明了集成电路
缩小计算机体积

C语言诞生 主流编程语言

Google!

Search the web using Google!

10 results ▾

Index contains ~25 million pages (soon to be much bigger)

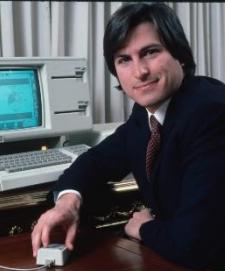
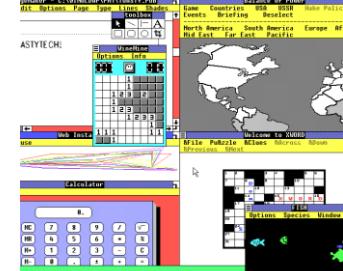
About Google!

[Stanford Search](#) [Linux Search](#)

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Copyright ©1997-8 Stanford University



History of Computer Science 2000 ~



1997/IBM
Deepblue首次打败人类
(国际象棋)



2003/AMD
Athlon 64
第一个64位CPU



2004/Mozilla
Firefox 1.0
挑战IE的网页浏览器



2005/谷歌
收购Android
开源手机操作系统



2006/Apple
MacBook Pro首次发布
第一台双核笔记本

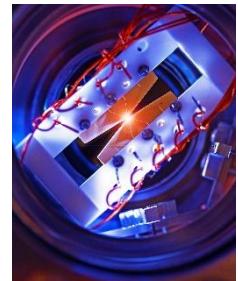
首次打败人类
AlphaGo围棋系统
2017/Deepmind

量子计算机问世
2016/Maryland

Apple Watch
2015/Apple

首次打败人类
Watson抢答系统
2011/IBM

第一代手持平板电脑 iPad
2010/Apple 第一代智能手机 iPhone 1
2007/Apple



History of Computer Science 2000 ~



2022/Stability AI
Stable Diffusion

2022/OpenAI
ChatGPT 聊天机器人

2023/OpenAI
GPT-4 图文交互

2024/OpenAI
Sora 视频生成

AI is shaping the future.



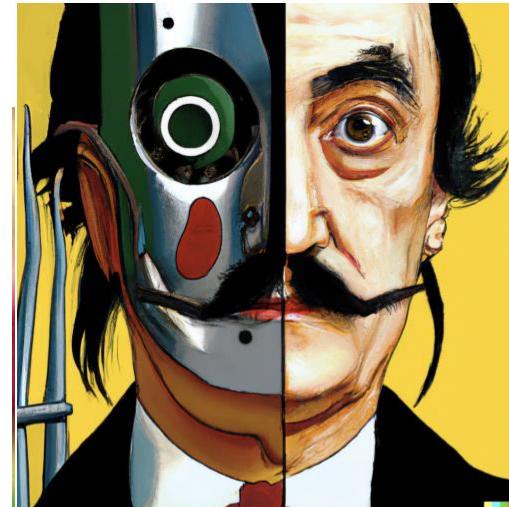
AI is having real-world impact

- Public imagination
 - Text assistants



AI 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

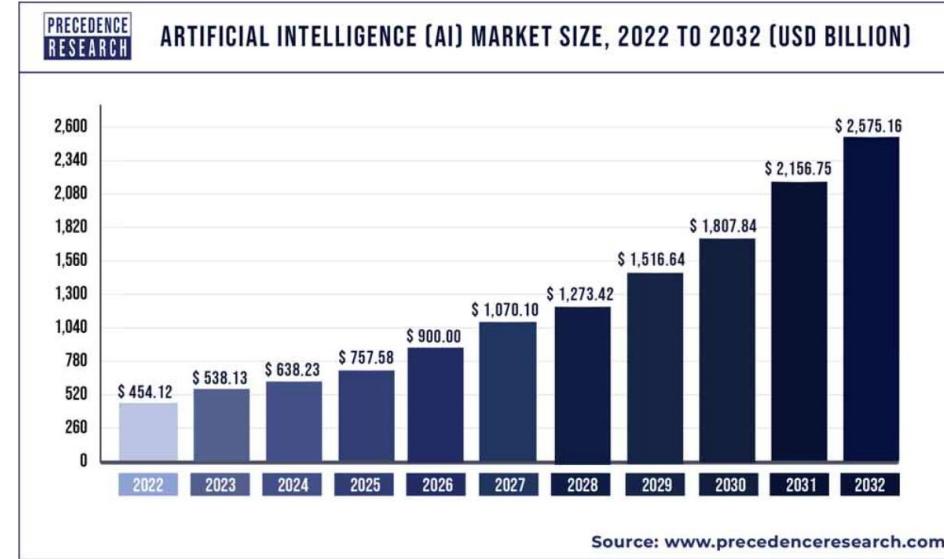


a corgi's head depicted as an explosion of a nebula

AI 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](http://www.precedenceresearch.com/artificial-intelligence-market)

AI is having real-world impact

- Public imagination
- Economy
- Politics



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AI is having real-world impact

- Public imagination
- Economy
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AI is having real-world impact

- Public imagination
- Economy
- Politics



AI 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

AI 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

AI is having real-world impact

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

nature
BIOTECH

AlphaFold Developers Win \$3-Million Breakthrough Prize in Life Sciences

DeepMind's system for predicting the 3D structure of proteins is among five recipients of science's most lucrative awards

By Zeeya Merali, Nature magazine on September 22, 2022

Nature, 2022

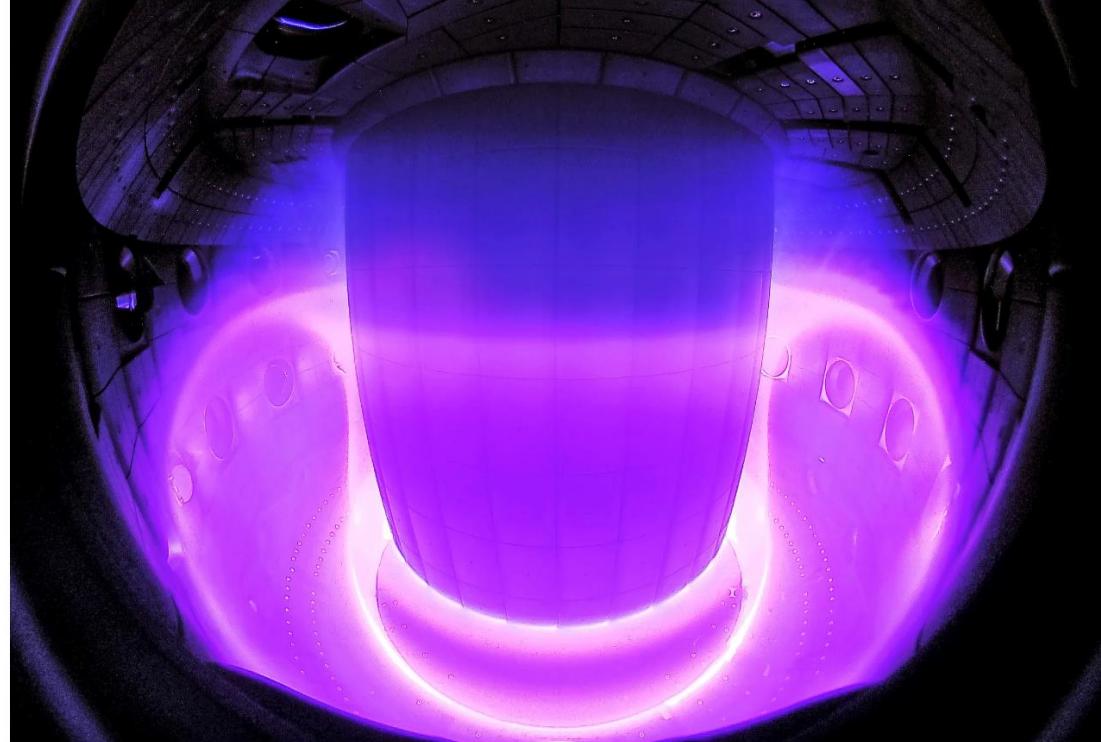
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- Sciences

AMIT KATWALA SCIENCE FEB 16, 2022 11:00 AM

DeepMind Has Trained an AI to Control Nuclear Fusion

The Google-backed firm taught a reinforcement learning algorithm to control the fiery plasma inside a tokamak nuclear fusion reactor.



PHOTOGRAPH: CURDIN WÜTHRICH, SPC/EPFL

Wired, 2022

AI is having real-world impact

- Public imagination
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- 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.

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2

Jan 18, 2023, 02:31pm EST

Forbes, 2023

AI is having real-world impact

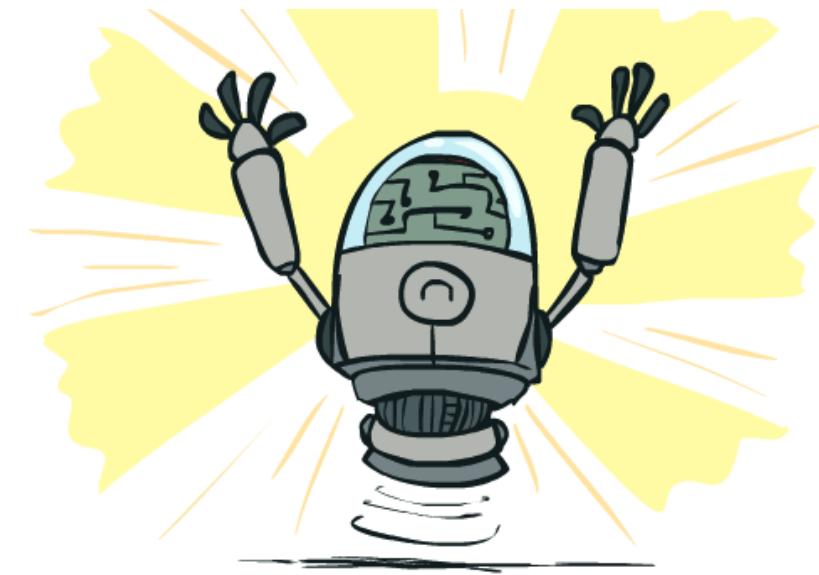
- Public imagination
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- Labor
- Sciences
- Education

Ok, but what actually is AI???

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 Shanghai?
- Buy a week's worth of groceries on the web?
- Buy a week's worth of groceries at FamilyMart?
- Discover and prove a new mathematical theorem?
- Perform a surgical operation?
- Translate spoken Chinese into spoken English in real time?
- Trade in real-world markets?
- Make money for humans, so humans can take it easy.
- 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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OpenAI's new o1 model can solve 83% of International Mathematics Olympiad problems

By HT News Desk | Edited by Abhyjith K. Ashokan

Sep 14, 2024 03:42 PM IST



OpenAI's new o1 model can be used for scientific research in physics, chemistry, and engineering, where rigorous reasoning and complex problem-solving are prime



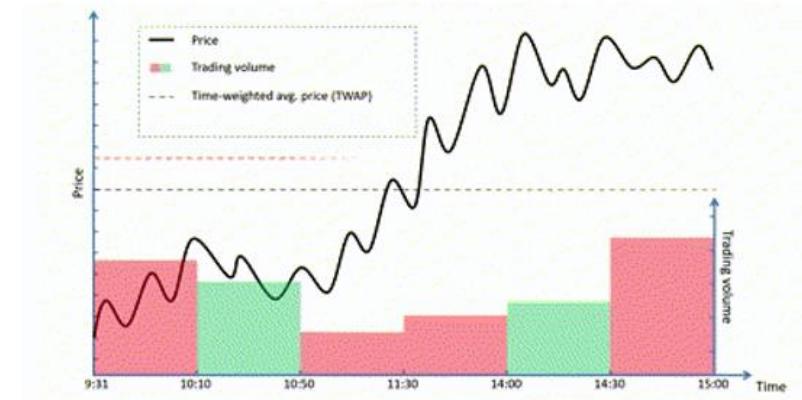
A symbol for the OpenAI virtual assistant on a smartphone, arranged in Riga, Latvia, on Friday, Aug. 16, 2024. (Andrey Rudakov/Bloomberg)

OpenAI will launch o1, its latest artificial intelligence (AI) model in two weeks. This will mark the debut of a new class of reasoning AI models and comes amid the speculation of the release of "Strawberry" AI.

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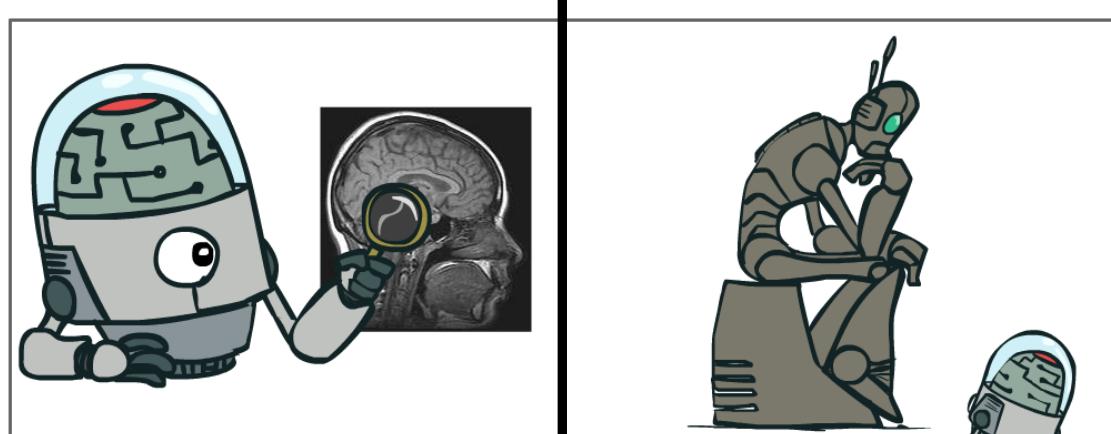
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What should we build?

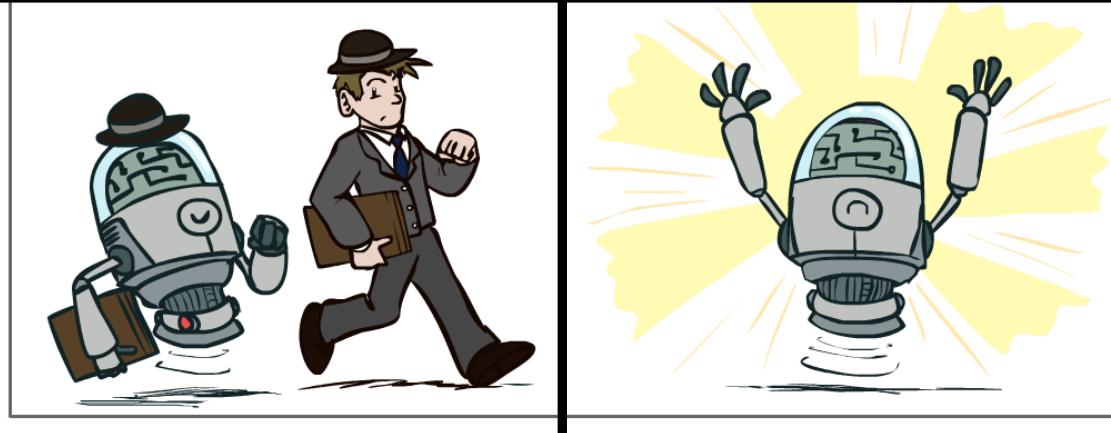
Should we make machines that...

Think like people?



Think rationally?

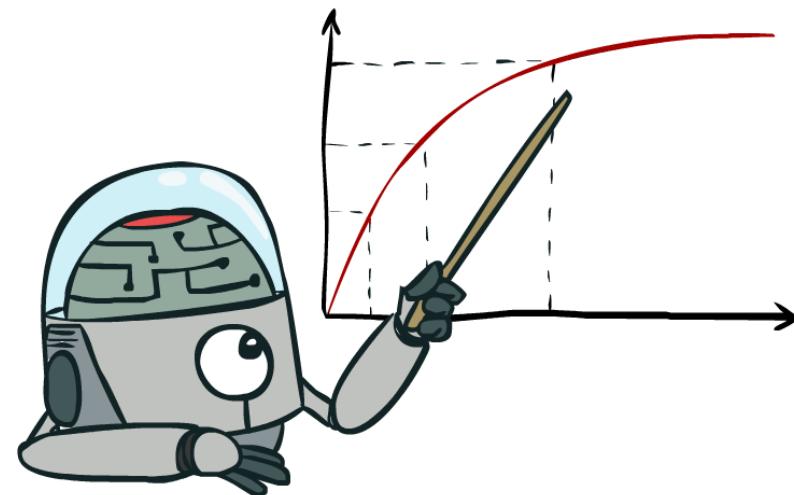
Act like people?



Act rationally?

Rational Decisions

- We'll use the term **rational** in a very specific, technical way:
 - Rational: *maximally achieving pre-defined goals*
 - Goals are expressed in terms of the **utility** of outcomes
 - World is uncertain, so we'll use **expected utility**
 - Being rational means acting to **maximize your expected utility**



Rational Decisions

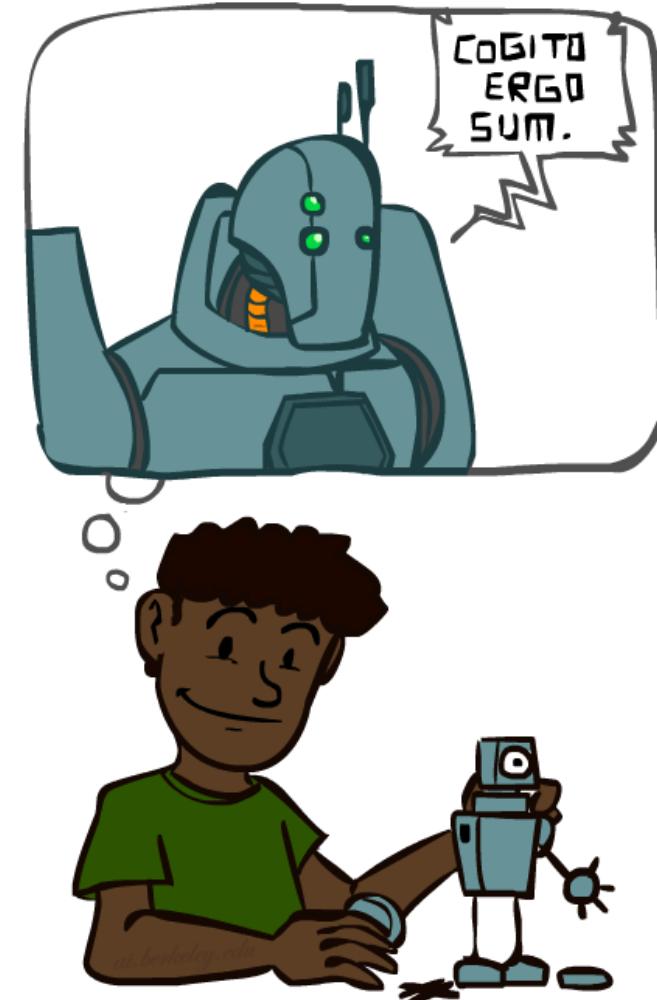
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 - World is uncertain, so we'll use **expected utility**
 - Being rational means acting to maximize your expected utility

A better title for this course might be:
Computational Rationality

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."



Turing Test

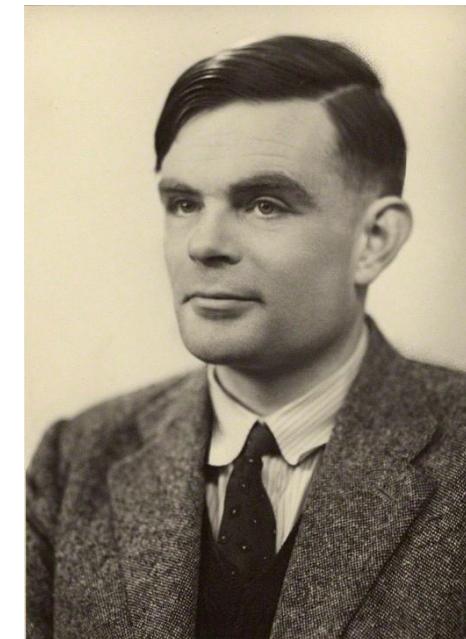
- Lots of early speculation & research
 - Turing: “Computing Machinery and Intelligence” (1950)

I.—COMPUTING MACHINERY AND INTELLIGENCE

BY A. M. TURING

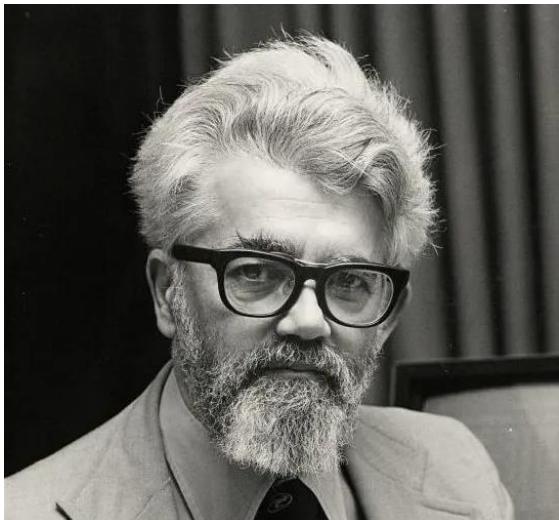
1. *The Imitation Game.*

I PROPOSE to consider the question, ‘Can machines think?’ This should begin with definitions of the meaning of the terms ‘machine’ and ‘think’. The definitions might be framed so as to reflect so far as possible the normal use of the words, but this attitude is dangerous. If the meaning of the words ‘machine’ and ‘think’ are to be found by examining how they are commonly used it is difficult to escape the conclusion that the meaning and the answer to the question, ‘Can machines think?’ is to be sought in a statistical survey such as a Gallup poll. But this is absurd. Instead of attempting such a definition I shall replace the question by another, which is closely related to it and is expressed in relatively unambiguous words.

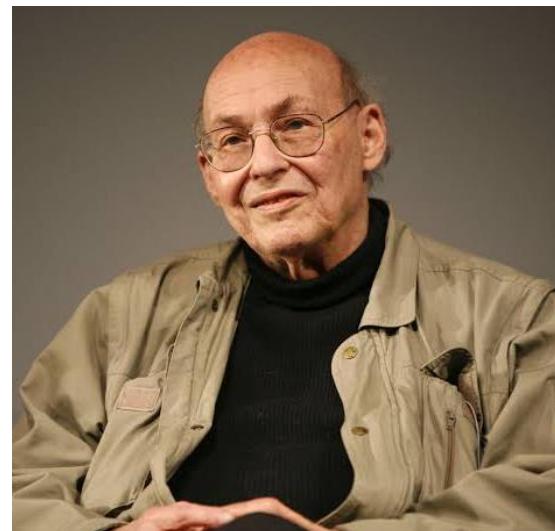


Dartmouth Conference

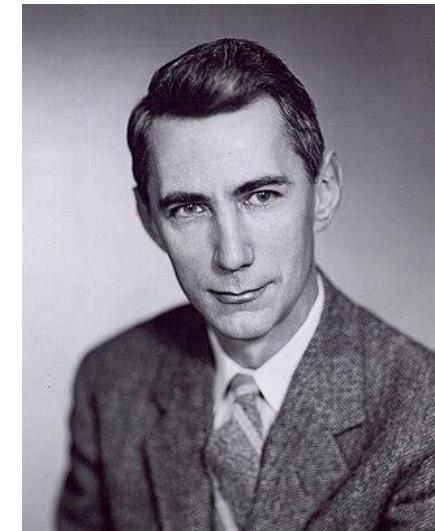
- Dartmouth Summer Research Project on Artificial Intelligence
 - The birth of artificial intelligence (AI) as a formal academic discipline



John McCarthy
Father of AI and Lisp



Marvin Minsky
Perceptrons



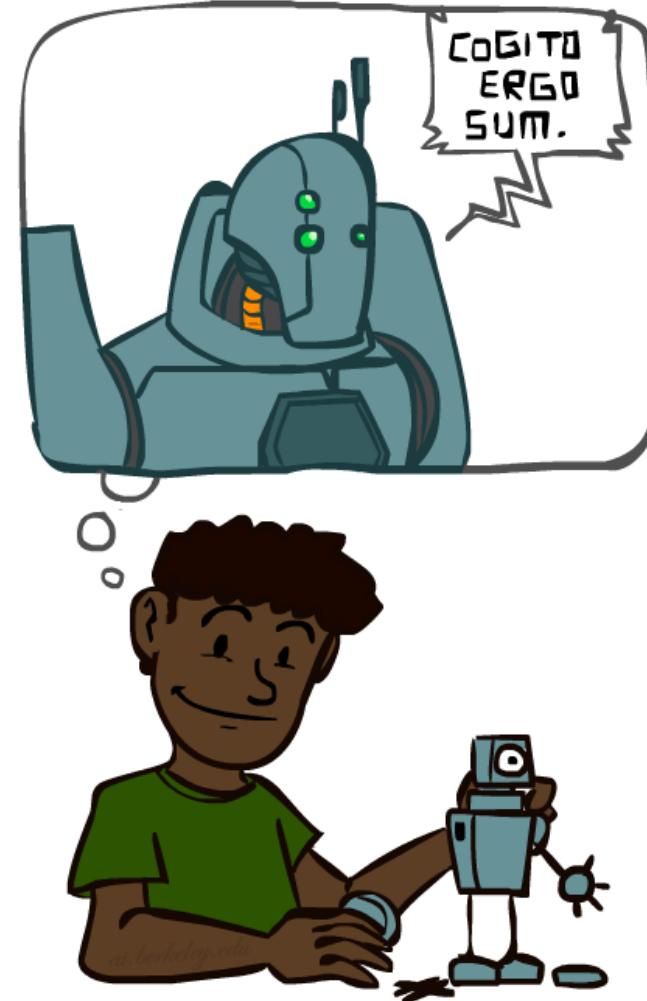
Claude Shannon
Information Theory



Nathaniel Rochester
Architect of IBM 701

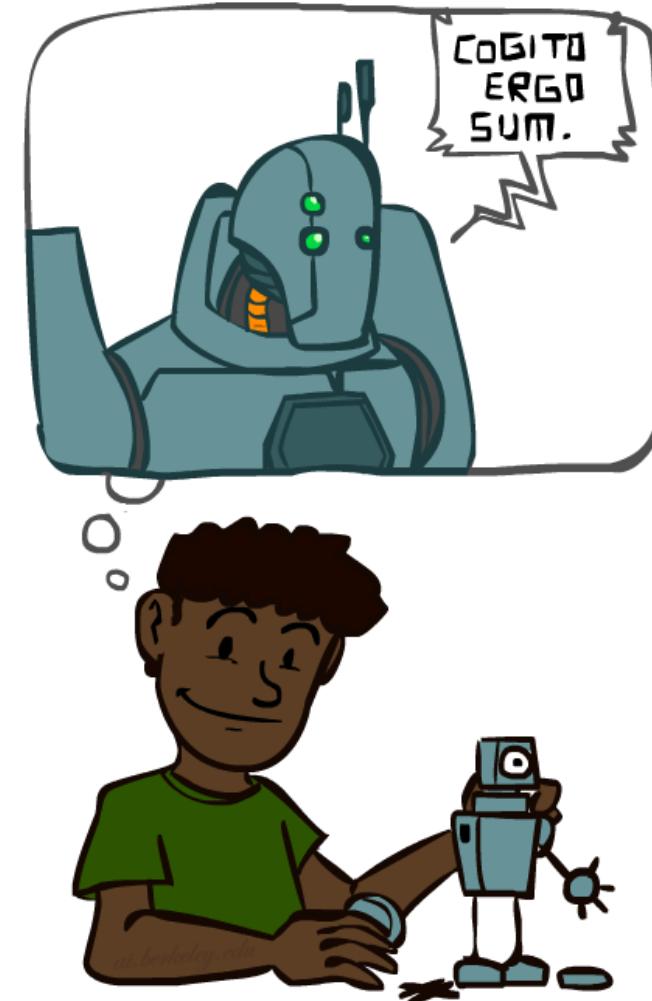
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 - 1950s: Early AI programs, including Samuel's checkers program, Newell & Simon's Logic Theorist, Gelernter's Geometry Engine
 - 1956: Dartmouth meeting: "Artificial Intelligence" adopted
 - 1969: Minsky & Papert: perceptrons can't learn XOR/parity!
- 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



AI Trends

- 2024 AI Index Report

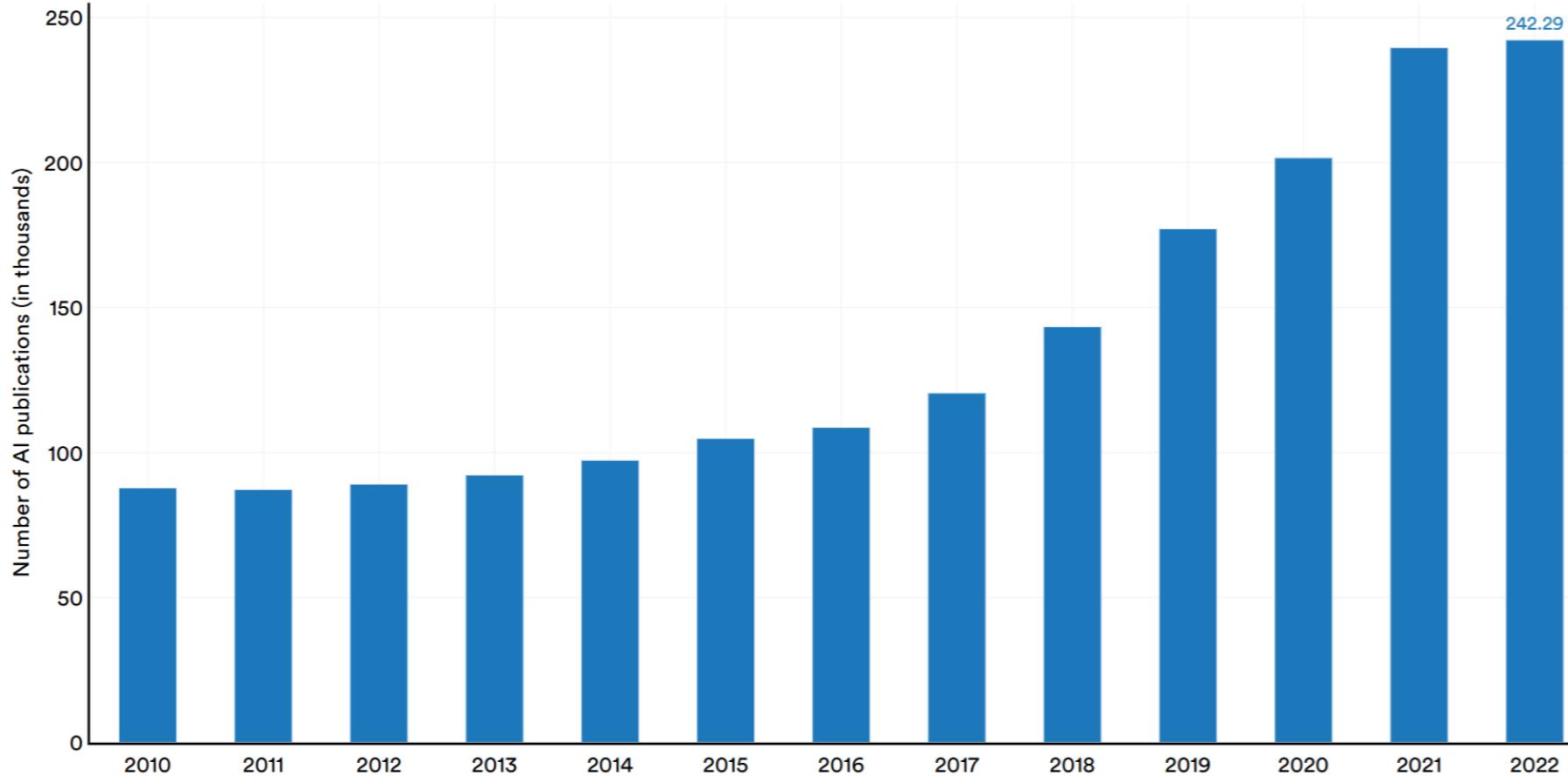


<https://aiindex.stanford.edu/report/>

AI Publications

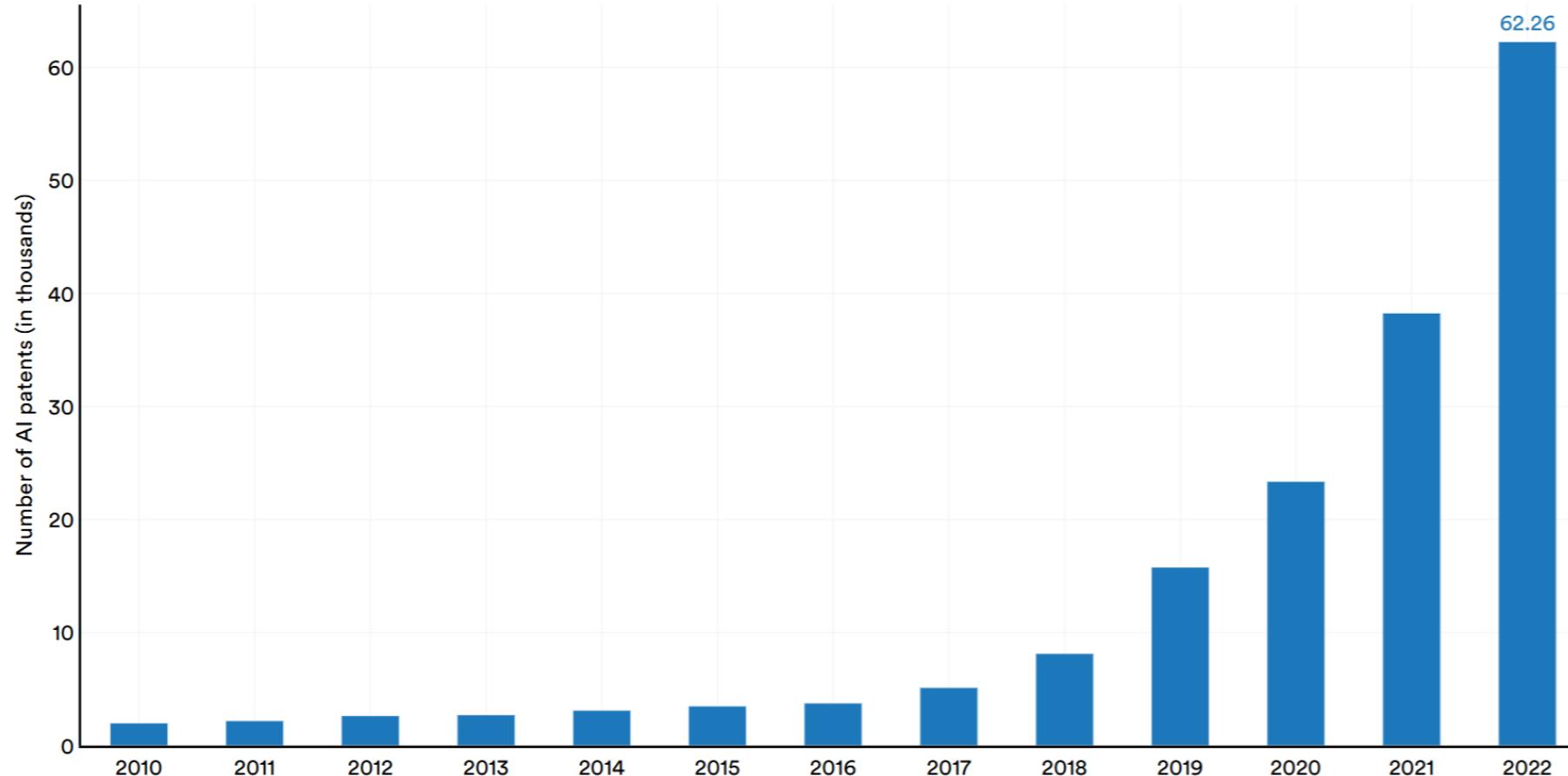
Number of AI publications in the world, 2010–22

Source: Center for Security and Emerging Technology, 2023 | Chart: 2024 AI Index report



AI Patents

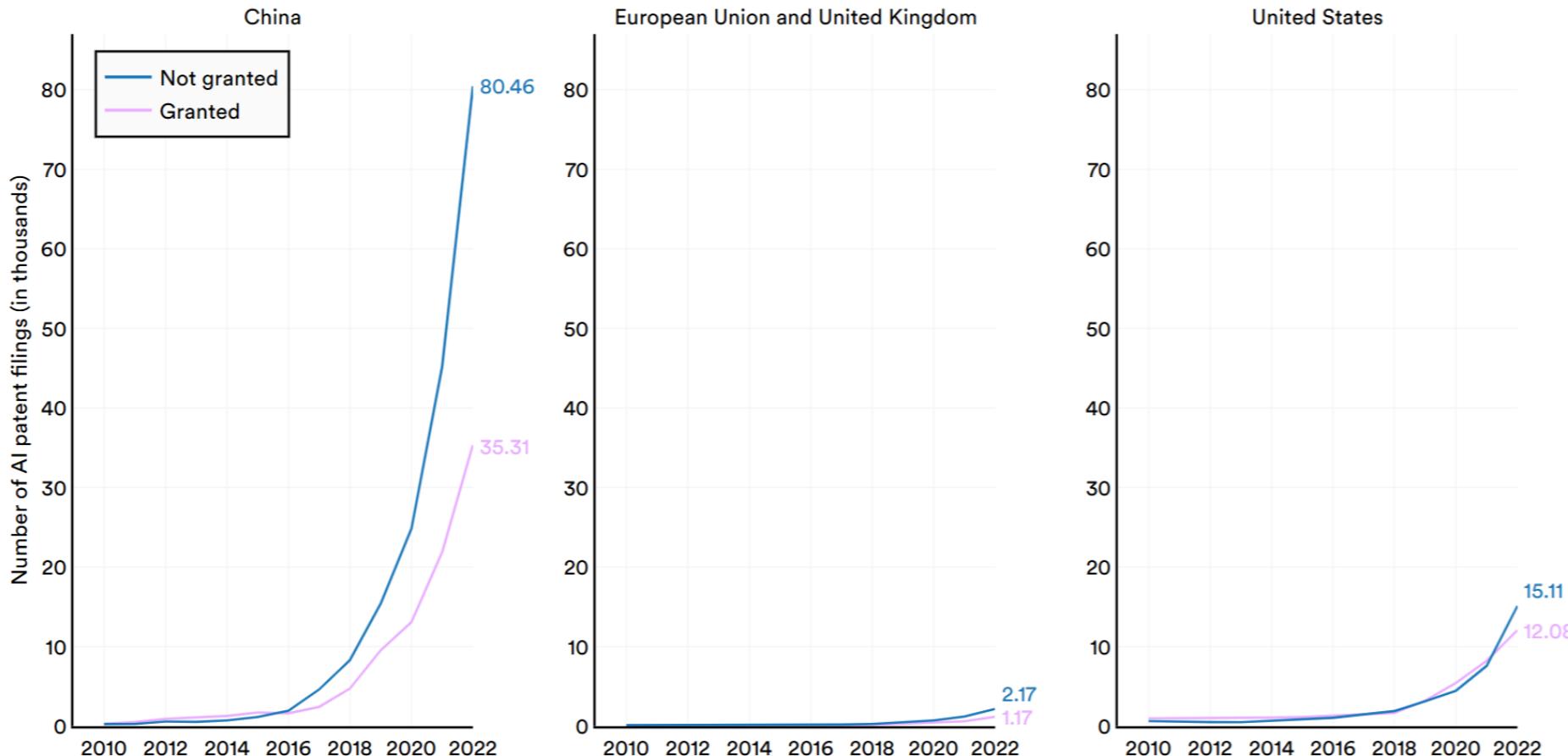
Number of AI patents granted, 2010–22
Source: Center for Security and Emerging Technology, 2023 | Chart: 2024 AI Index report



AI Patents

AI patents by application status by geographic area, 2010–22

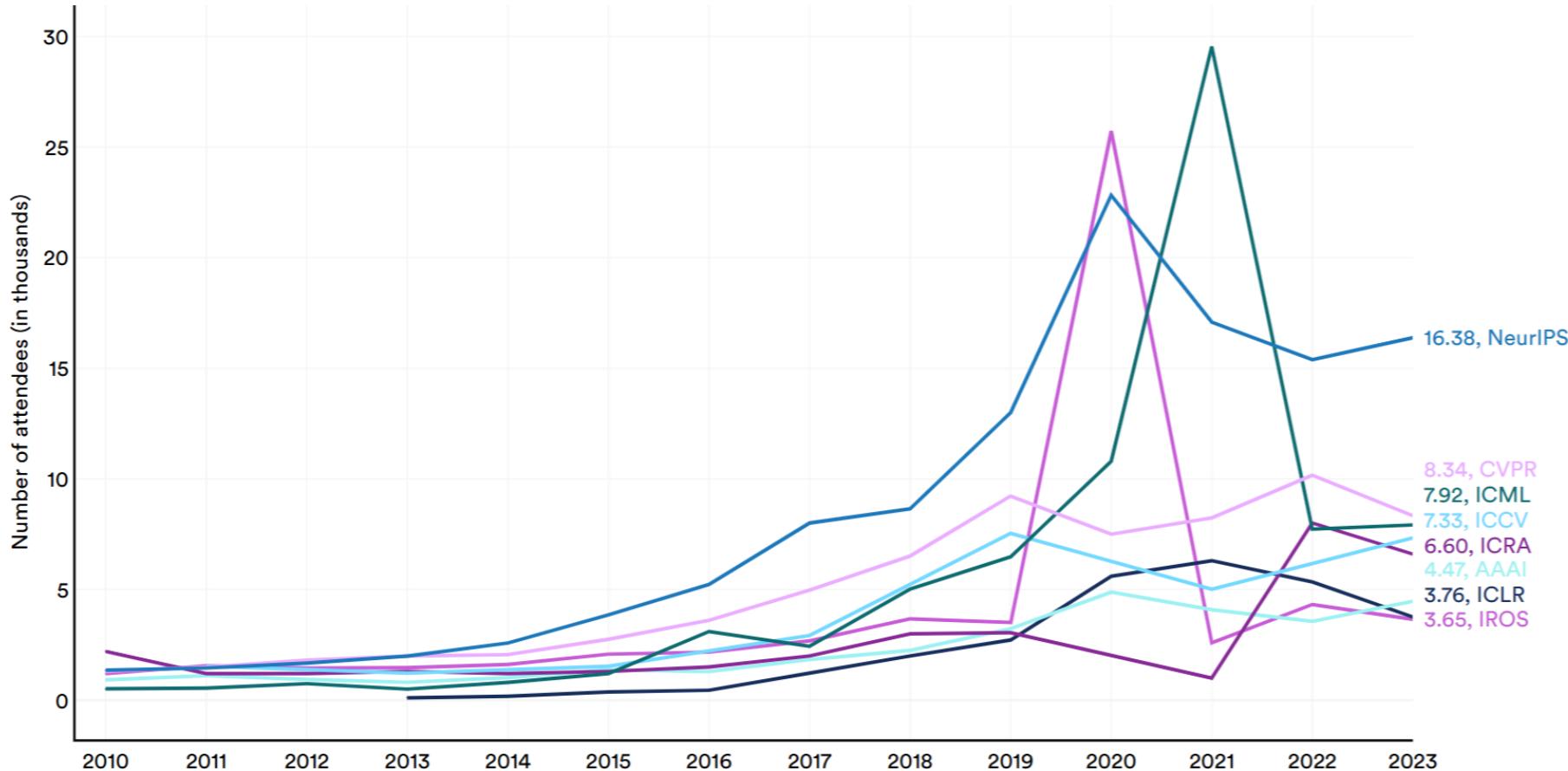
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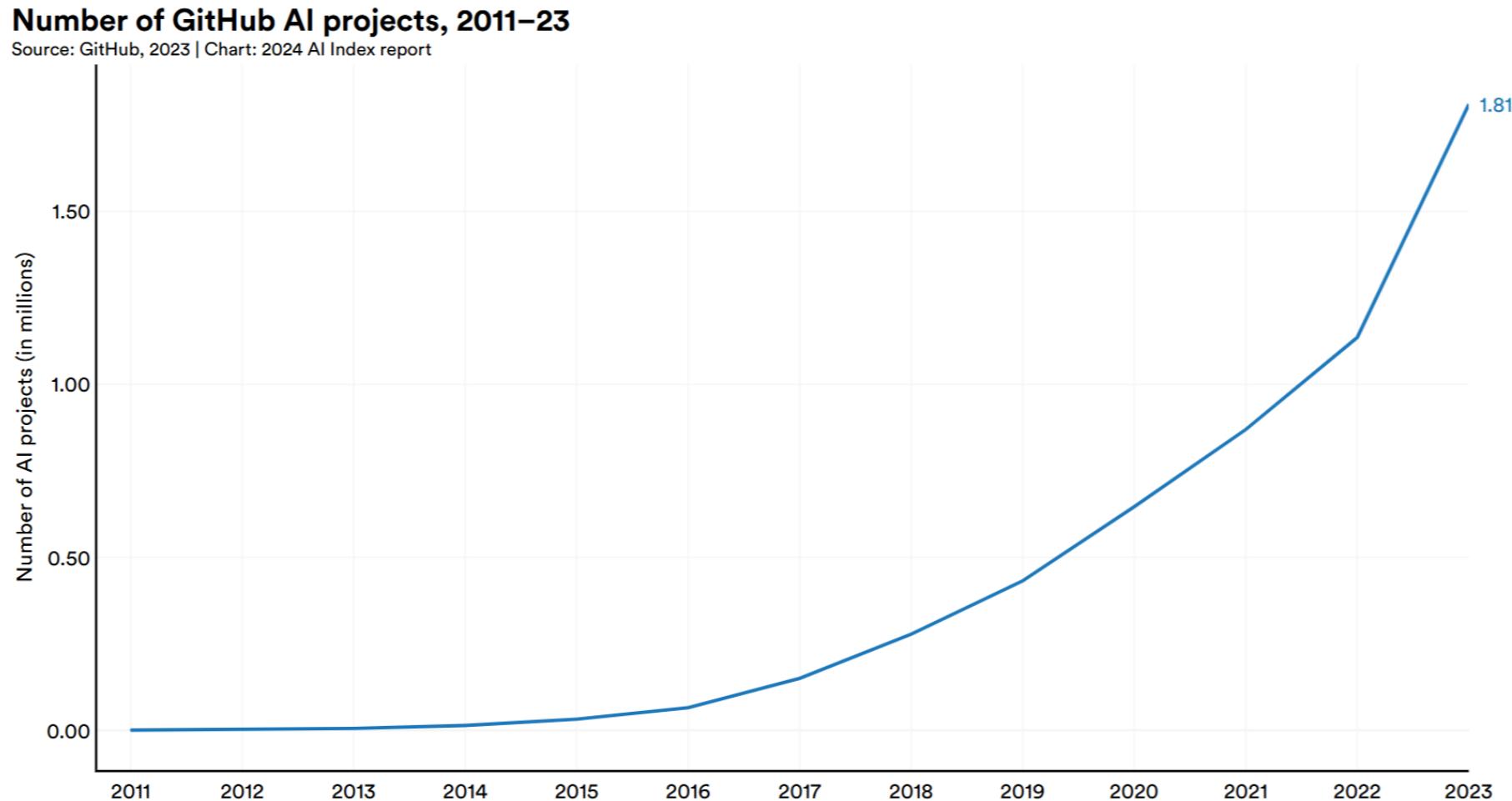
Conference Attendance

Attendance at large conferences, 2010–23

Source: AI Index, 2023 | Chart: 2024 AI Index report



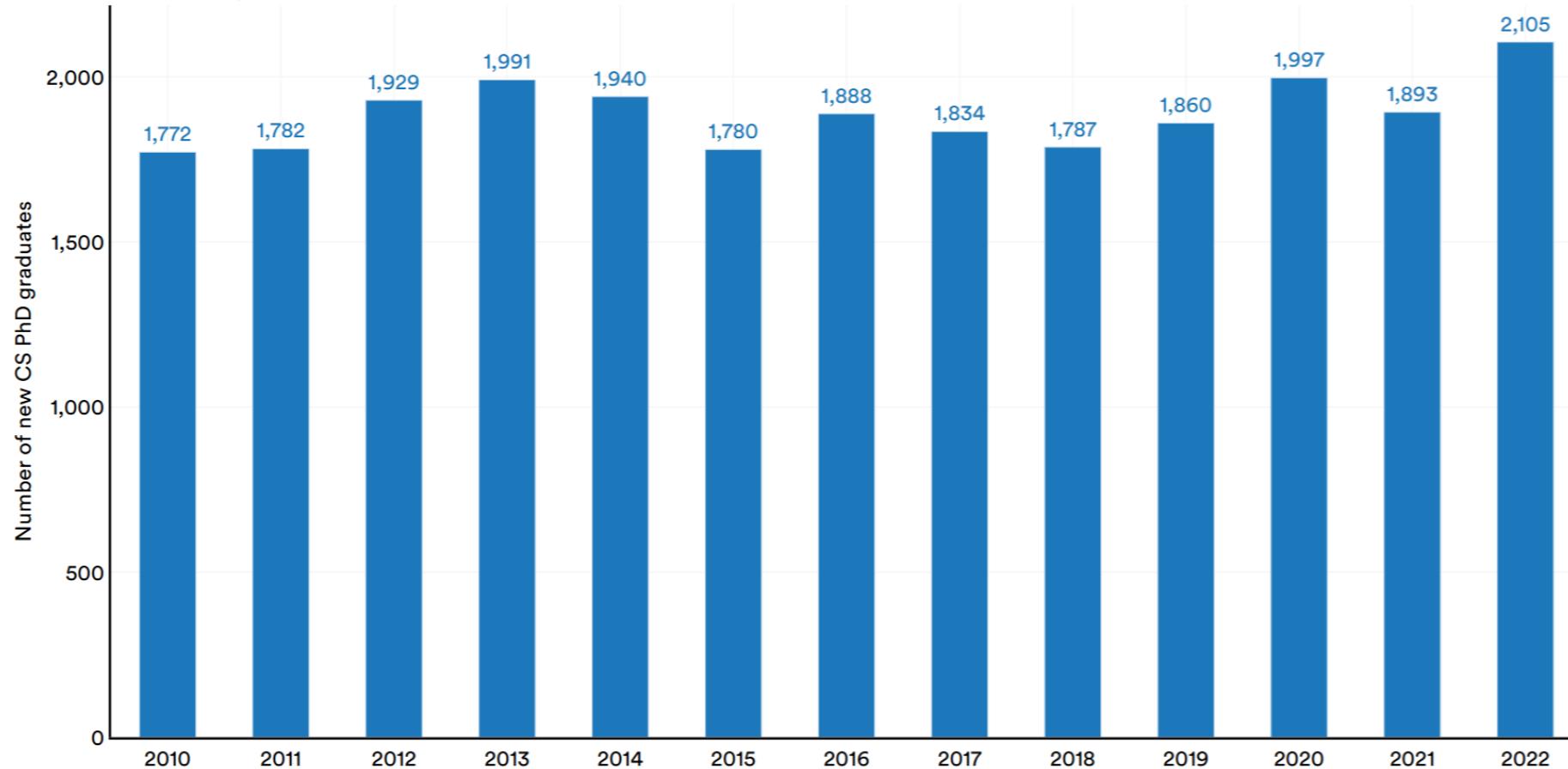
Open-source Projects



CS PhD

New CS PhD graduates in the United States and Canada, 2010–22

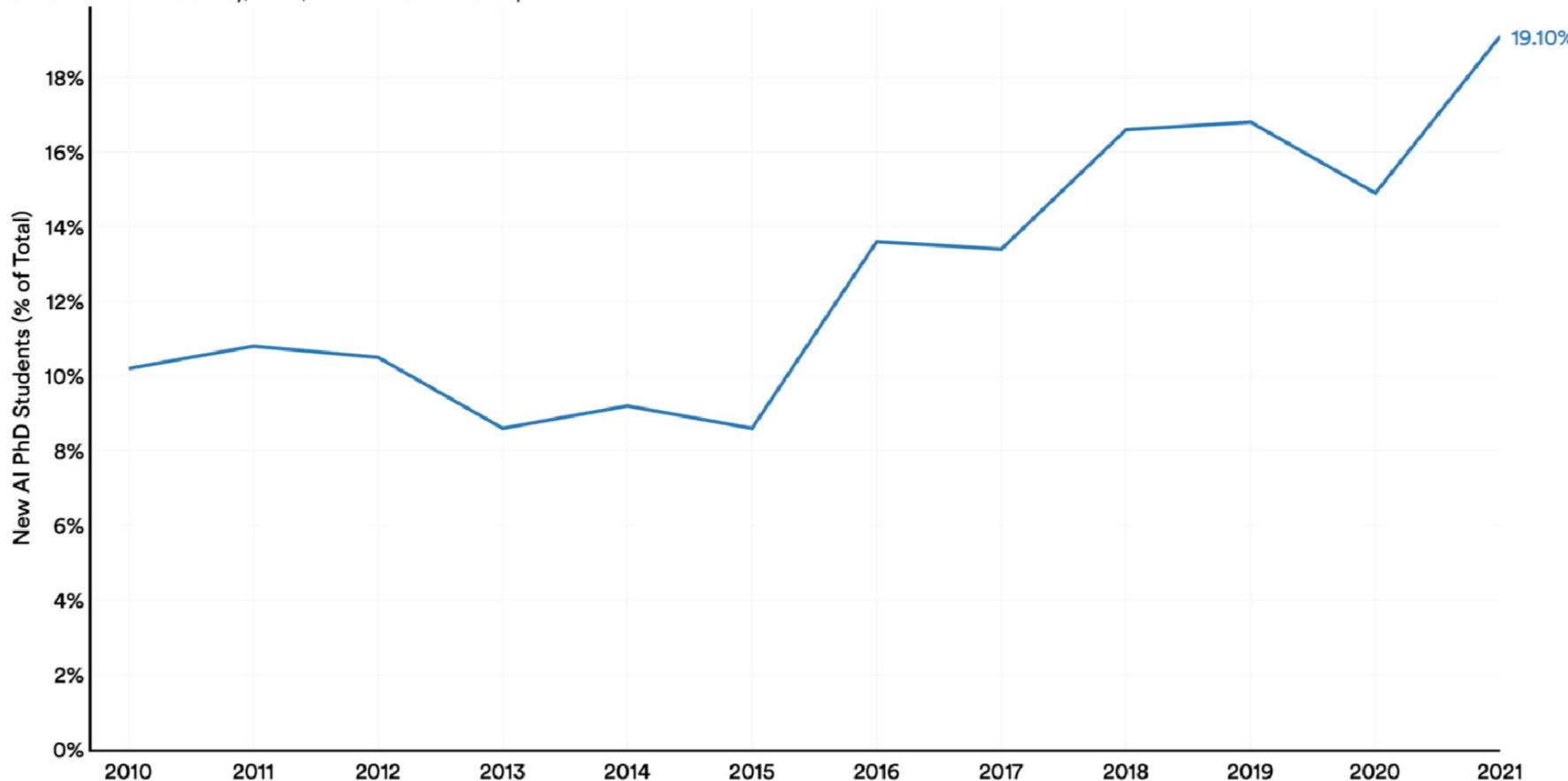
Source: CRA Taulbee Survey, 2023 | Chart: 2024 AI Index report



CS PhD

New CS PhD Students (% of Total) Specializing in AI, 2010–21

Source: CRA Taulbee Survey, 2022 | Chart: 2023 AI Index Report



Subfields of AI

Integration

Multi-Agent System

Robotics

Modality-Specific

Natural Language
Processing

Computer
Vision

Speech
Recognition

Foundation

Machine
Learning

Knowledge
Representation
& Reasoning

Uncertainty
in AI

Weak & Strong AI

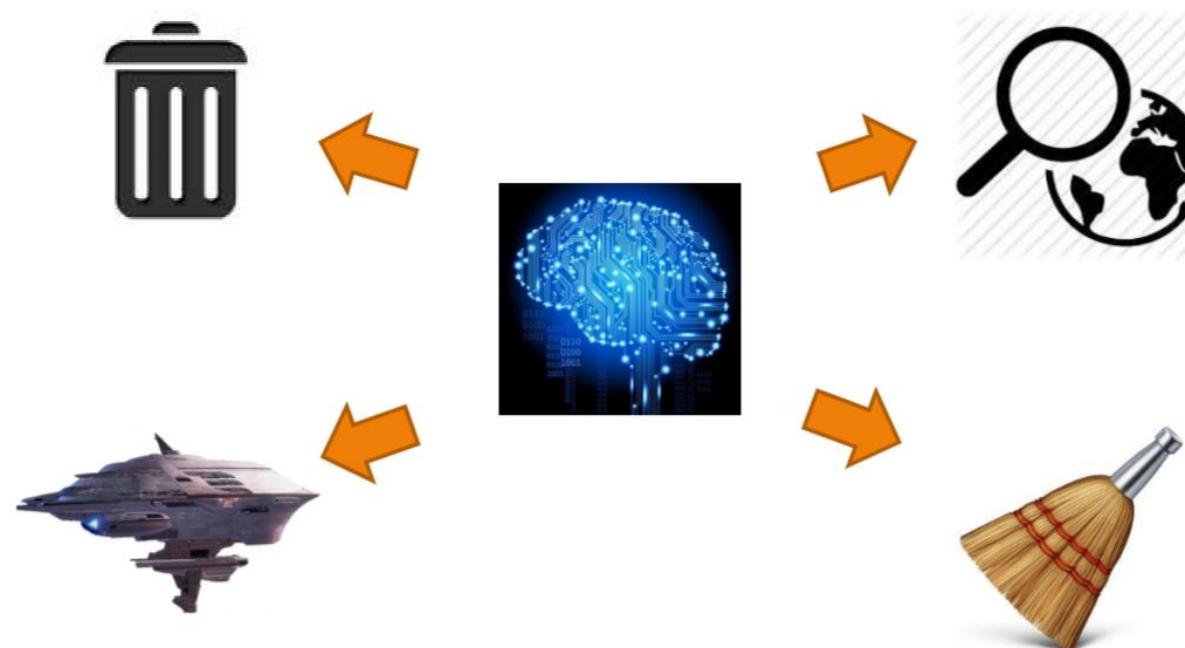
- Weak AI (Applied AI)
 - AI that accomplishes specific tasks



Weak & Strong AI

- **Strong AI (General AI)**

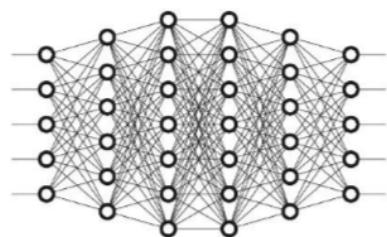
- human-like intelligence – AI that could successfully perform any intellectual task that a human can



Three Types of AI Approaches

Symbolism

$$\begin{array}{cccc} + & - & \times & \div \\ \neg & \vee & \perp & \approx \\ \in & \cap & \subseteq & \Sigma \\ \partial & \nabla & \wedge & \Pi \end{array}$$



Connectionism



Statistical Approaches

Symbolism

- Representing knowledge with symbols and their compositions (expressions)
 - Inference and learning is done by manipulating symbols (e.g., logic)

$$\begin{aligned} \forall x \forall y, & Human(x) \wedge Place(y) \wedge At(x, y) \wedge Rain(y) \\ & \rightarrow \exists z, Umbrella(z) \wedge Use(x, z) \end{aligned}$$

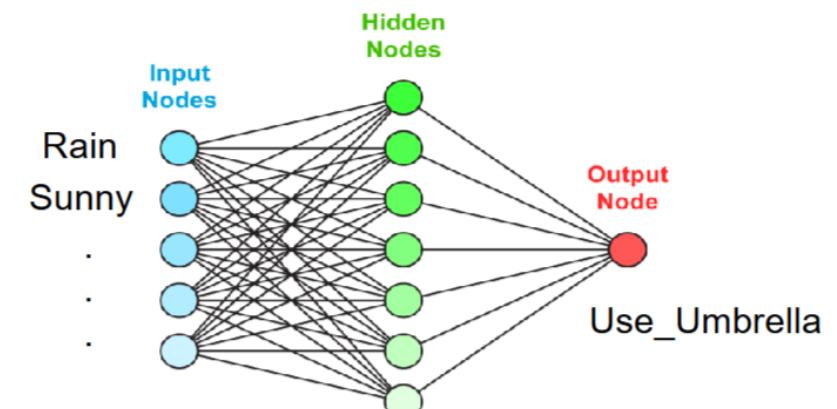
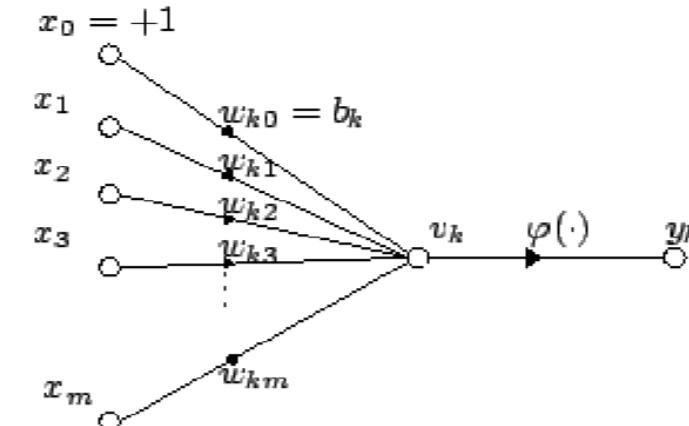
Symbolism

- **History**

- Dominant during 1950s – 1980s
- Fell out of favor in 1980s – 1990s
- Integration with statistical approaches (2000s)
- Integration with neural approaches (2010s)

Connectionism

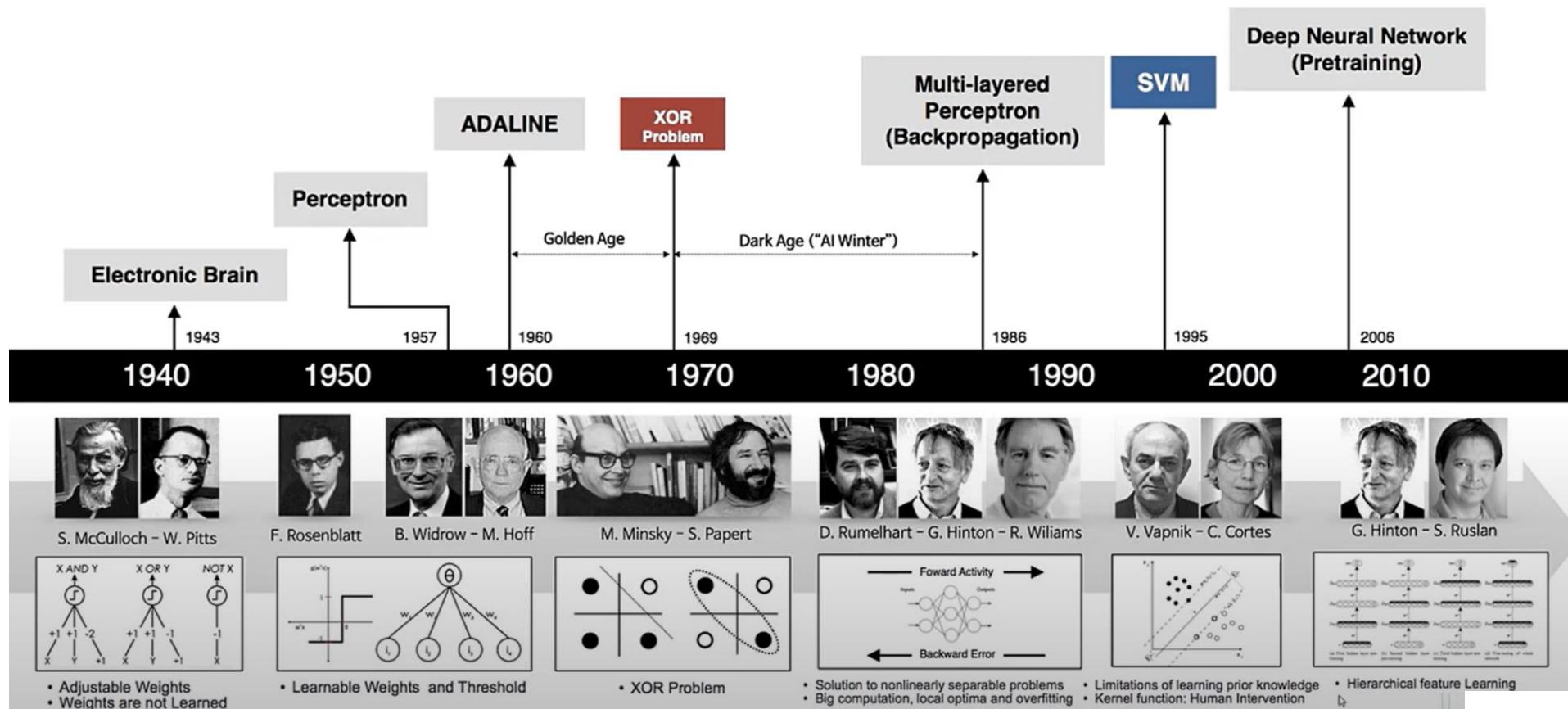
- Representing knowledge with interconnected networks of simple units
 - Neural networks
- Inference
 - Follow the computation specified by the network from input to output
- Learning
 - optimization of connection weights



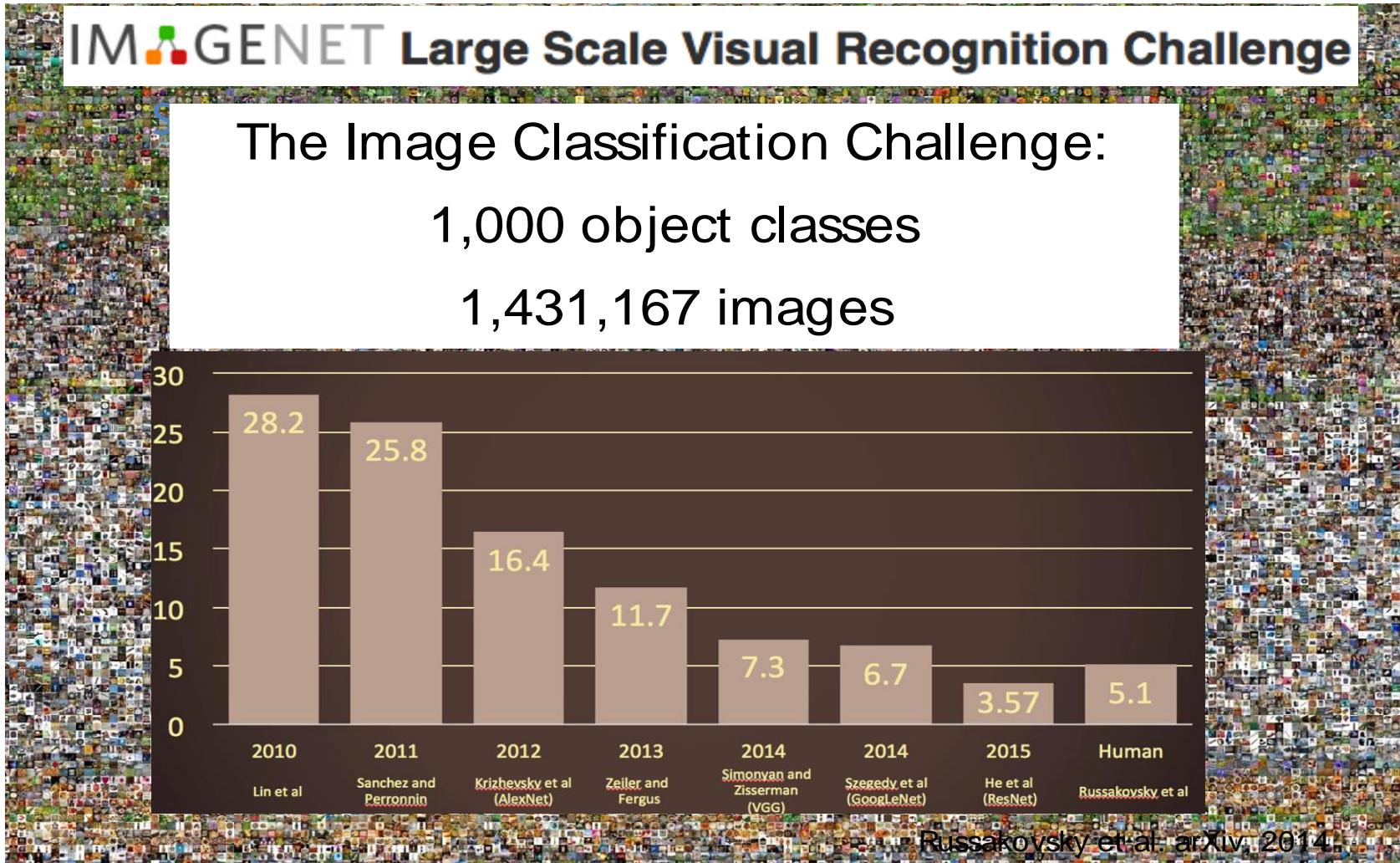
Connectionism

- History of connectionism: rose and fell for several times
 - 1940s: pioneer work, e.g., McCulloch-Pitts model
 - 1958: invention of perceptron (Rosenblatt)
 - 1969: “Perceptron” published (Minsky & Papert)
 - Publicized key issues of perceptron (e.g., XOR)
 - 1970s: AI winter
 - 1980s: revival of connectionism
 - Hopfield net, BP algorithm
 - Rumelhart & McClelland (1986): Parallel Distributed Processing
 - 1990s-2000s: overtaken in popularity by other methods
 - 2010s: rise of deep learning
 - Since ~2012: dominates CV
 - Since ~2015: dominates NLP

Connectionism



Connectionism



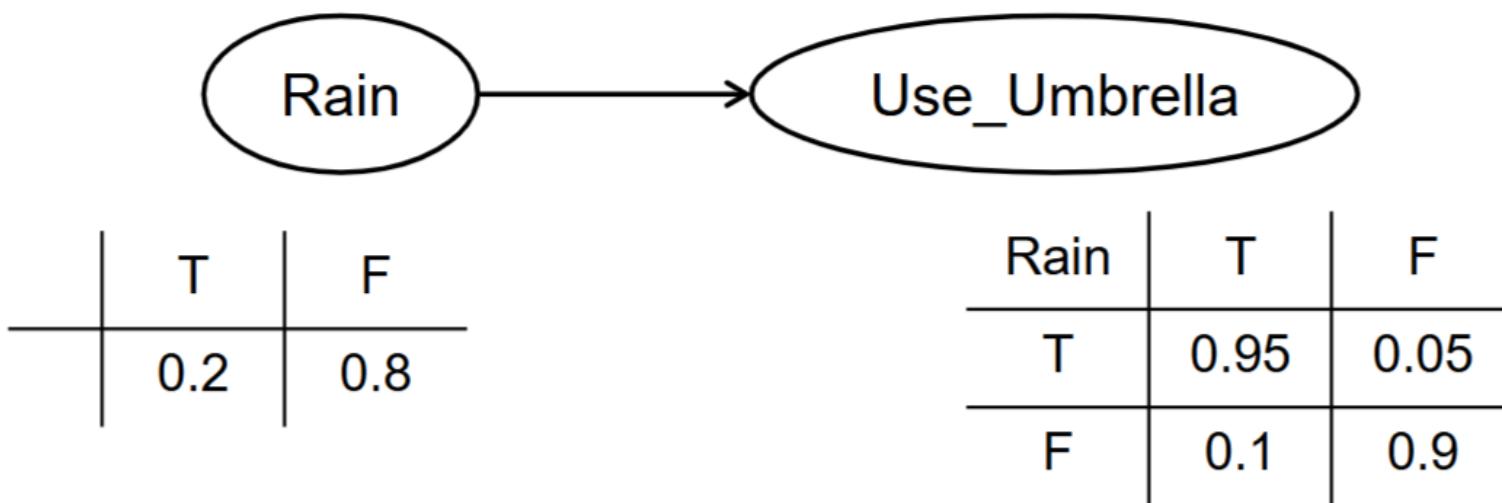
Connectionism



ACM Turing Award 2019 (*Nobel Prize of Computing*)
Yann LeCun, Geoffrey Hinton, and Yoshua Bengio

Statistical Approaches

- Representing knowledge with probabilistic models
- Inference and learning is done by probabilistic inference

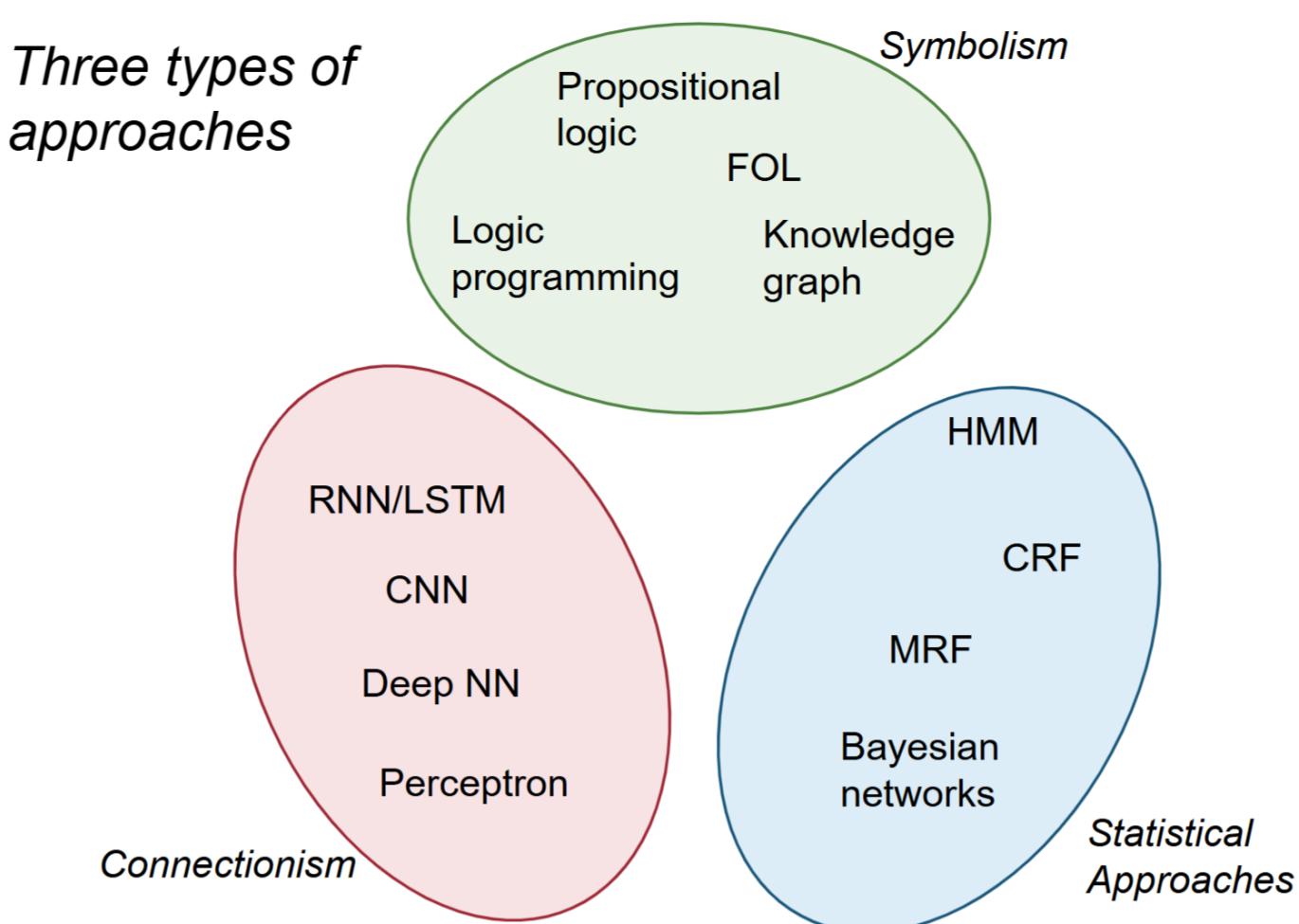


Statistical Approaches

- History

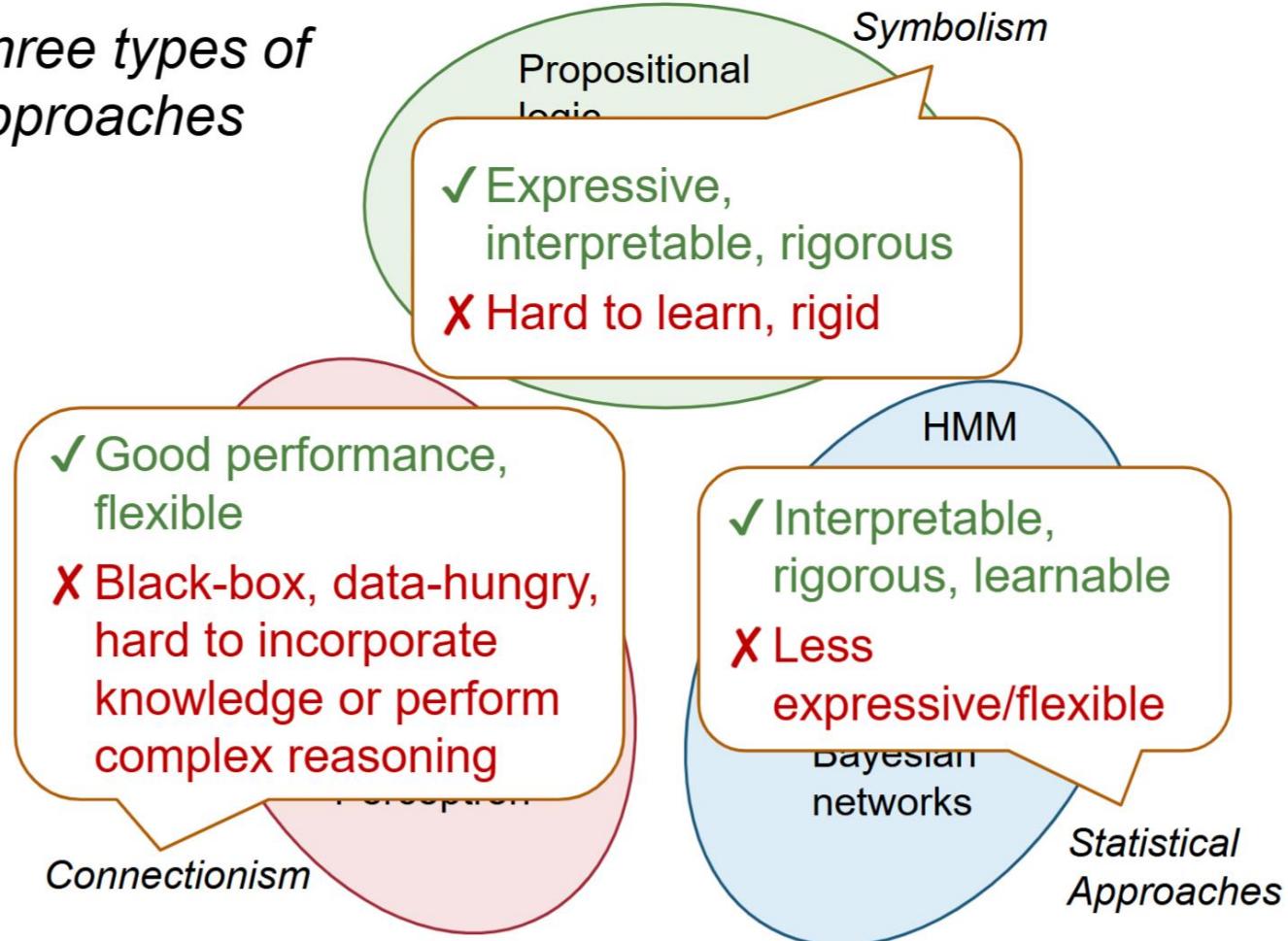
- Become popular since 1990s
- Dominant during 2000s
- Overshadowed by deep learning in 2010s

Three types of AI approaches

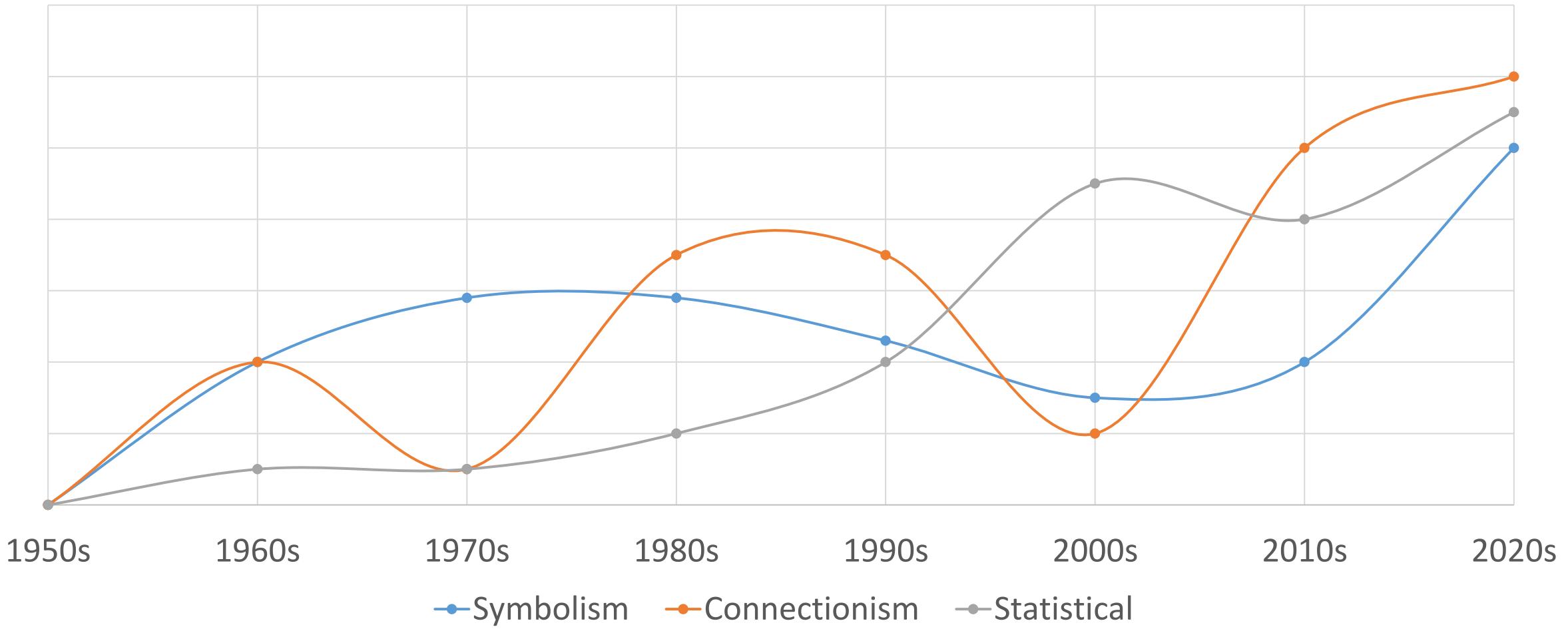


Three types of AI approaches

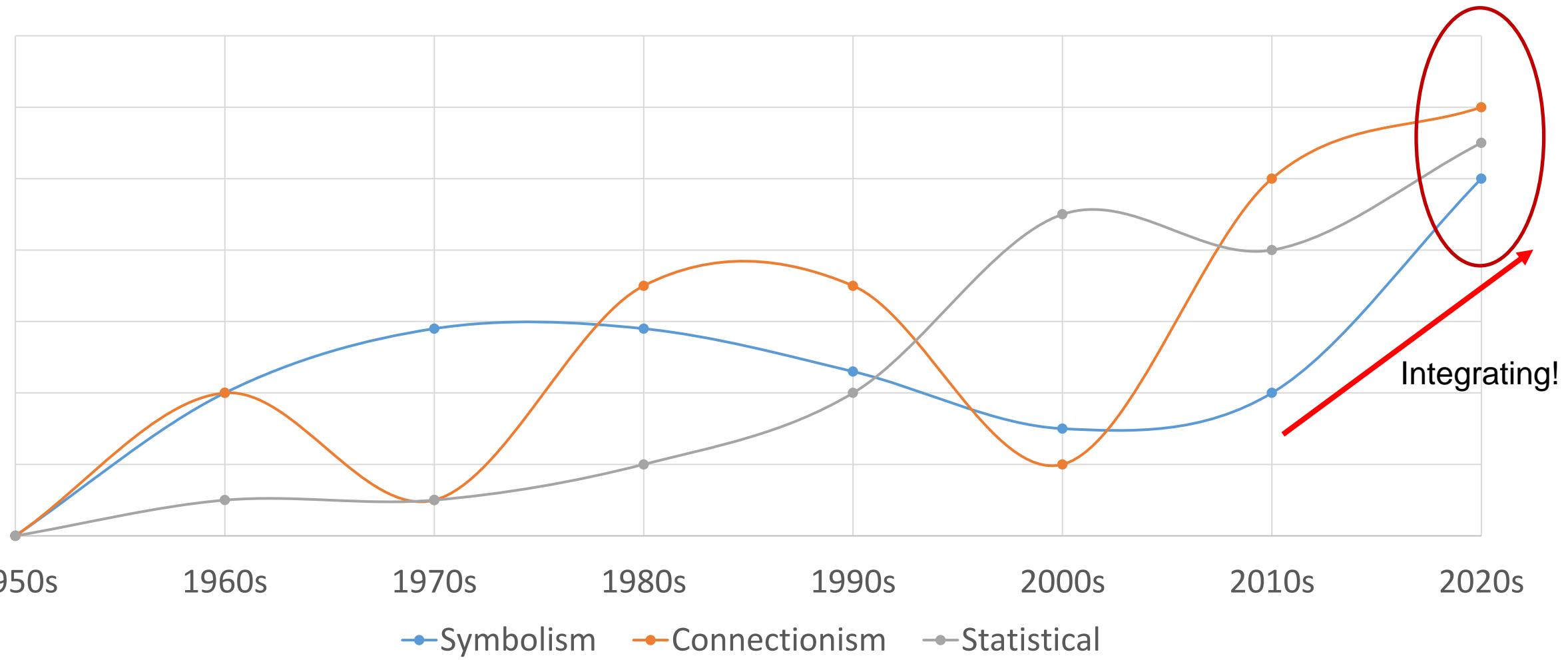
Three types of approaches



Three types of AI approaches

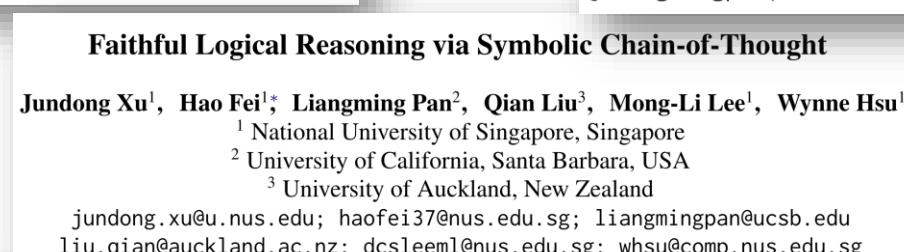
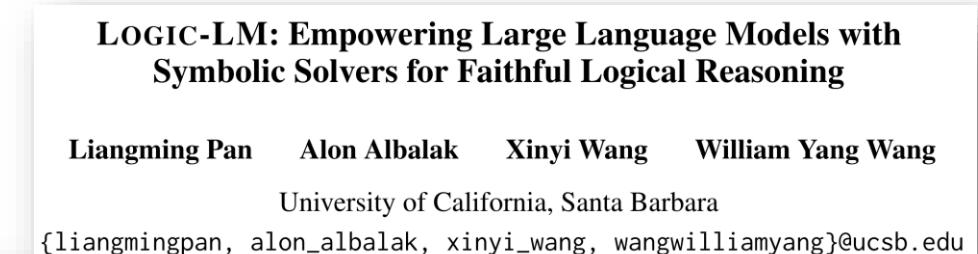
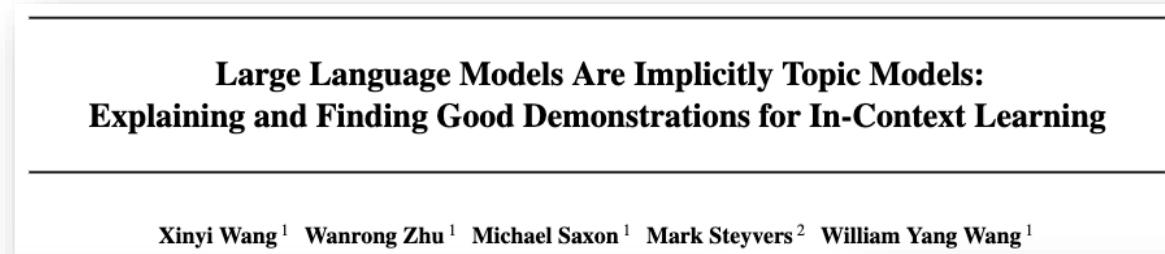


Three types of AI approaches

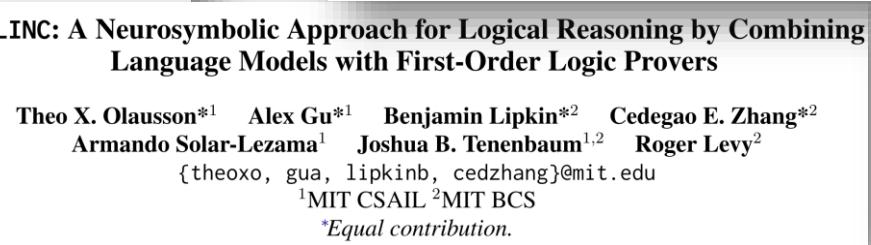


AI Agents

- Three main streams of AI technique are merging.



ICLR 2022



Sang Michael Xie, Aditi Raghunathan, Percy Liang, Tengyu Ma
Stanford University
{xie, aditir, pliang, tengyuma}@cs.stanford.edu

AI Agents

Examples	Capabilities	Limitations
"Explain quantum computing in simple terms" →	Remembers what user said earlier in the conversation	May occasionally generate incorrect information
"Got any creative ideas for a 10 year old's birthday?" →	Allows user to provide follow-up corrections	May occasionally produce harmful instructions or biased content
"How do I make an HTTP request in Javascript?" →	Trained to decline inappropriate requests	Limited knowledge of world and events after 2021

ChatGPT

Model: Code Interpreter ALPHA

I want you to OCR an image and give me a .txt file

Trigger OCR functions

Sure, I can help you with that. Please provide me with the image you'd like to OCR (optical character recognition) so that I can extract the text and create a .txt file for you.

Finished working Show work ↘

The text has been successfully extracted from the image and saved to a .txt file. You can download the .txt file from the following link: [ocr-output.txt](#).

Please let me know if there is anything else I can assist you with!

create a shepard tone and save it as a wav file. please also explain what's the mystery of this.

The Shepard tone is an auditory illusion that creates the impression of a continuously ascending or descending pitch that seems to rise or fall forever, without ever reaching a peak or bottom. This effect is achieved by layering multiple sine waves, each separated by an octave. As one pitch seems to ascend, the lower frequencies fade out, and higher frequencies fade in, giving the listener the perception of a never-ending rise or fall in pitch.

The Shepard Tone Illusion Breakdown:

1. **Multiple Octaves:** Several tones are played simultaneously, spaced one octave apart.
2. **Volume Modulation:** The higher-frequency tones gradually increase in volume, while lower-frequency tones decrease. This creates a seamless transition.
3. **Circularity:** When the highest tone fades out, the lowest tone fades in again at a frequency that's one octave higher, tricking the listener into perceiving a continuous rise or fall.

This illusion plays on the brain's perception of sound and pitch, causing us to think we're hearing an endlessly rising or falling tone, even though there is no infinite range of sound.

Creating the Shepard Tone:

```
#!/usr/bin/python
# Create a rising Shepard tone by increasing frequency by powers of 2 (octaves)
# and applying a volume envelope to simulate the rising/falling illusion
# and then saving it as a wav file
# Author: [REDACTED]
# Date: [REDACTED]
# Version: [REDACTED]
# License: [REDACTED]
# GitHub: [REDACTED]
# Email: [REDACTED]
# Description: [REDACTED]
# This script generates a Shepard tone by creating multiple sine waves of increasing frequency and volume, spaced by octaves, and then applying a volume envelope to create the illusion of a continuous rise or fall in pitch. The output is a WAV file.
```

I'll create a Shepard tone now and save it as a WAV file for you.

已分析 ↘

I have created the Shepard tone and saved it as a WAV file. You can download it using [Download Shepard Tone](#).

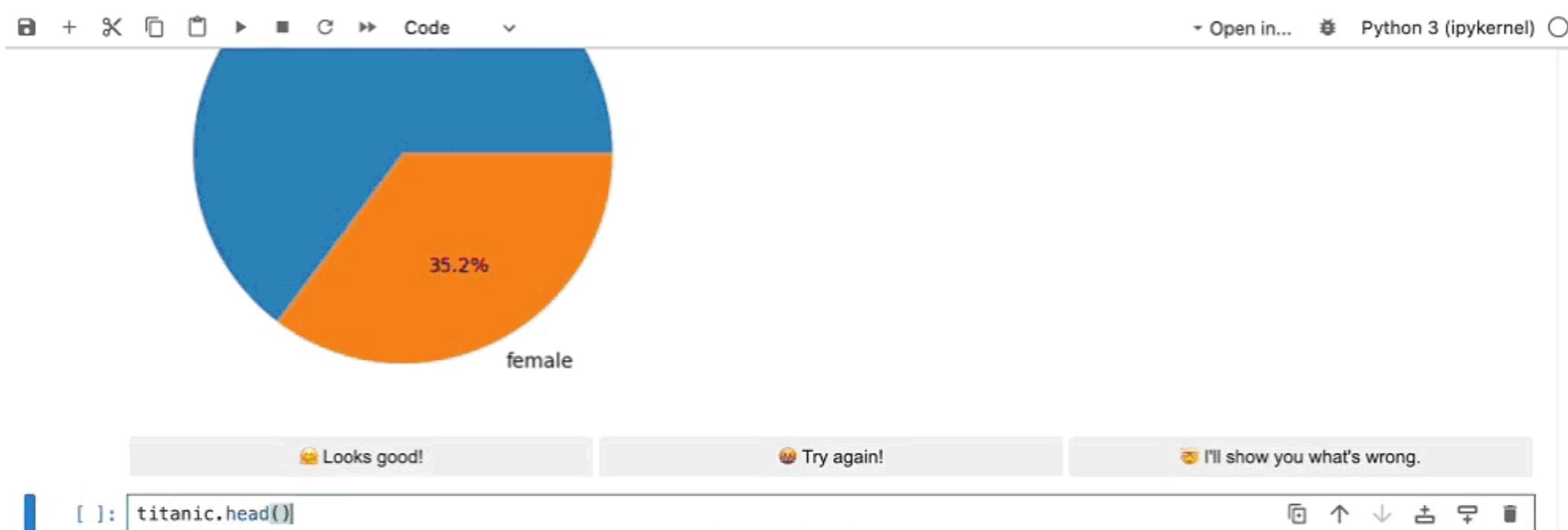
Enjoy the mysterious illusion! Let me know if you need any more adjustments. ↘

给"ChatGPT"发送消息

Creating sound

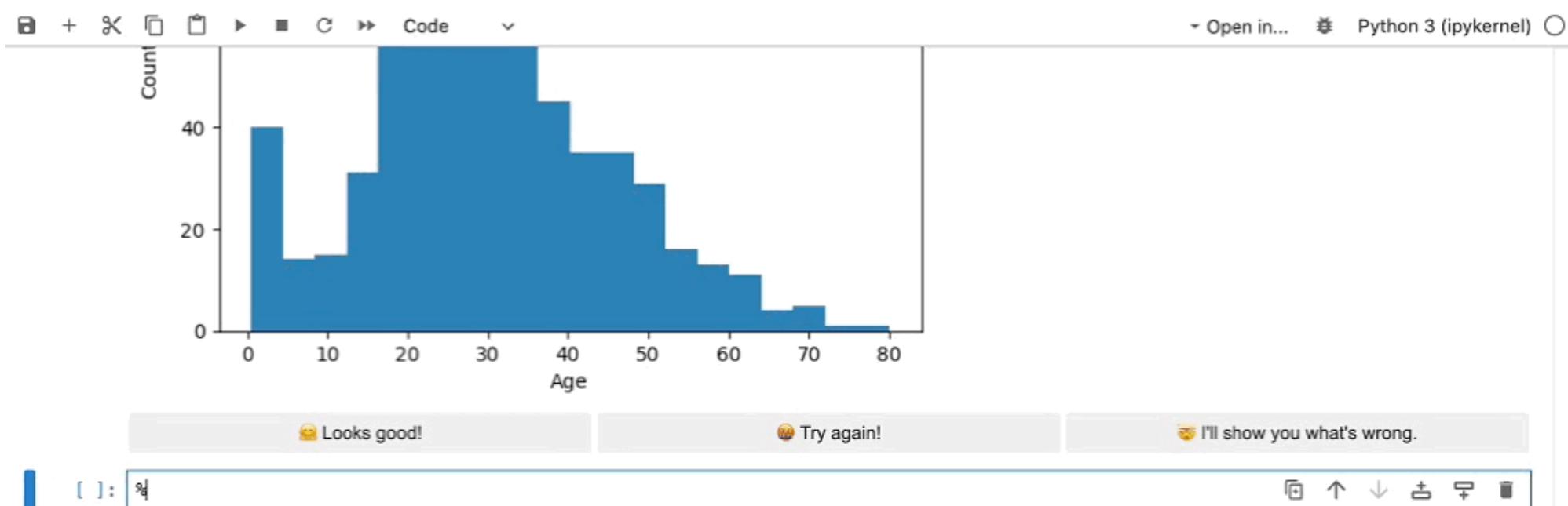
AI Agents

- Solving data science problem



AI Agents

- Solving data science problem



AI Agents

- Complex generative tasks
 - Please generate a new image based on the pose of IMAGE1 and the description of IMAGE2.

Human : please based on the pose image of  [Image] and the description of  [Image] , generate a new image



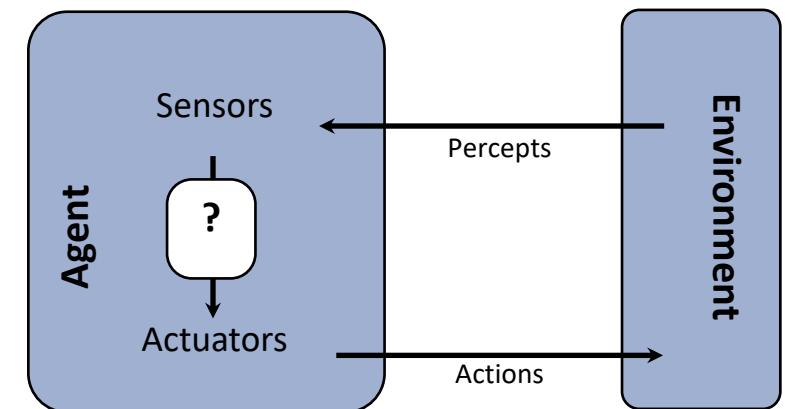
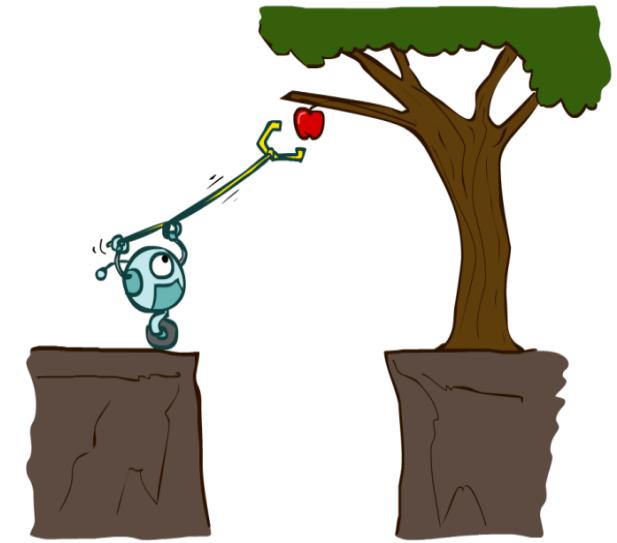
HuggingGPT : Based on the pose image of  [Image] and the description of  [Image] , I have generated a new image for you. The process of generating this image involved using the openpose-control model to extract the pose information from the basketball image, and then using the image-to-text model to generate a description of the boy in the image. Finally, I used the openpose-text-to-image model to combine the pose information and the description to generate the final image. The complete path of the generated image is  [Image] . If you have any other questions, please let me know.



Submit

This Course: Designing Rational Agents

- An **agent** is an entity that perceives and acts.
- A **rational agent** selects actions that maximize its (expected) **utility**.
- Characteristics of the **percepts**, **environment**, and **action space** dictate techniques for selecting rational actions
- This course is about:
 - General AI techniques for a variety of problem types
 - Learning to recognize when and how a new problem can be solved with an existing technique



COURSE CONTENT OVERVIEW

Course Topics

Core Components of Rational Agents:

Search & Planning

Probability & Inference

Supervised Learning

Reinforcement Learning

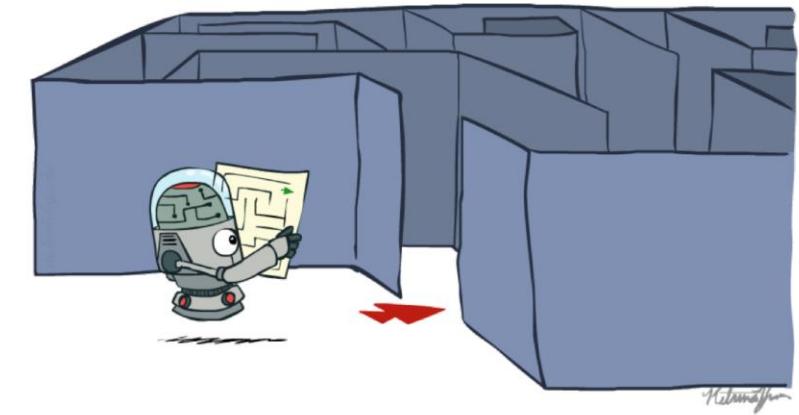
Course Topics

Search &
Planning

Probability &
Inference

Supervised
Learning

Reinforcement
Learning



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

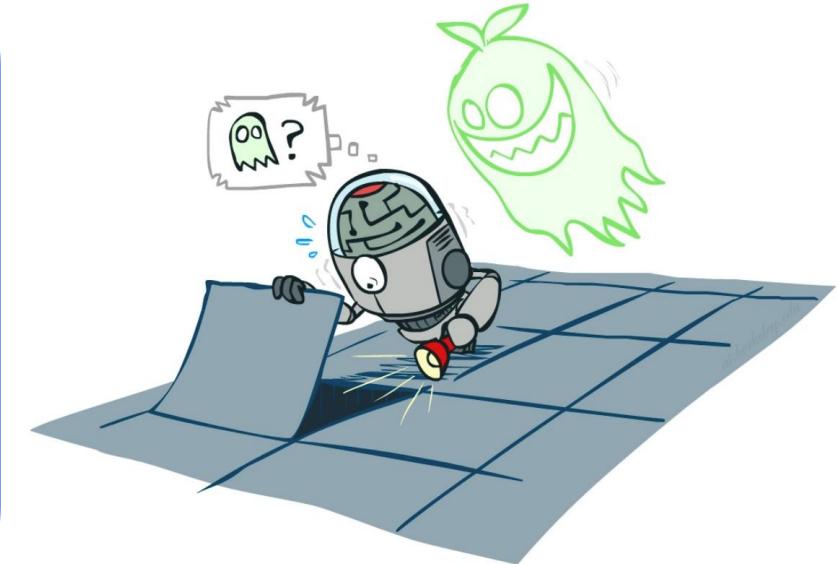
Course Topics

Search &
Planning

Probability &
Inference

Supervised
Learning

Reinforcement
Learning



How can I make sense of *uncertainty*?

Course Topics

Search &
Planning

Probability &
Inference

Supervised
Learning

Reinforcement
Learning



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

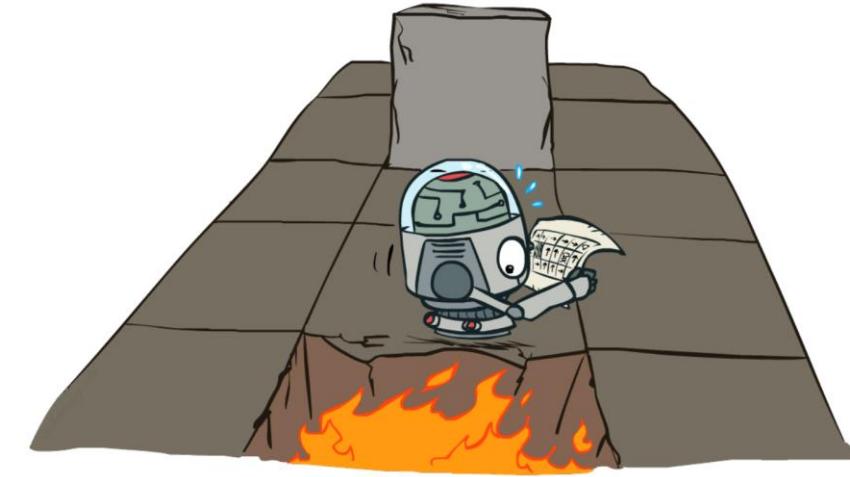
Course Topics

Search &
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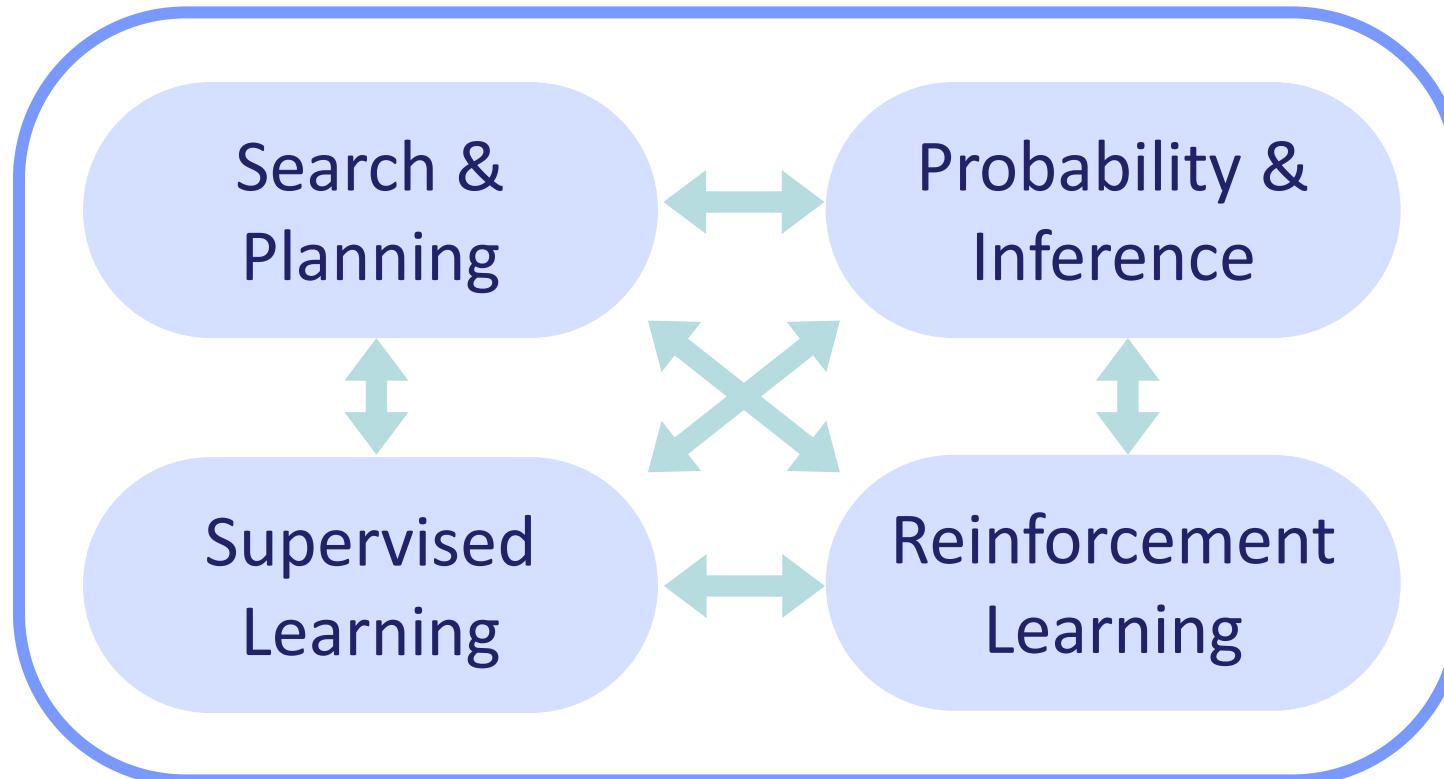
Probability &
Inference

Reinforcement
Learning



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

Course Topics



Course Topics

Search &
Planning

Probability &
Inference

Supervised
Learning

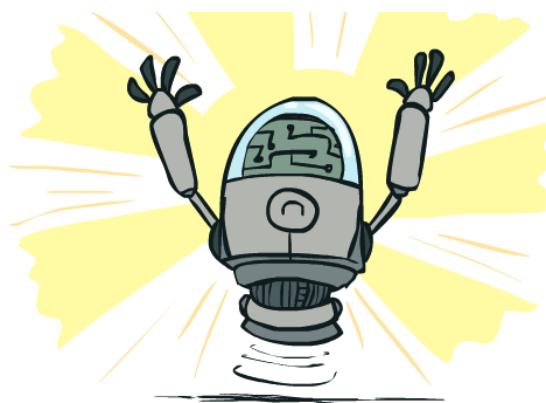
Reinforcement
Learning

Applications

Impact on Sciences, Technology, Society

By the end of this course you'll:

- Build and understand math of rational, learning agents
- Select and apply the right AI methods for wide range of problems
- Recognize how these methods are used in modern AI systems
- Be prepared to make decisions on how AI is used in society



Course Contents

- Search
- Constraint satisfaction problems
- Game
- Propositional logic
- First-order predicate logic
- Probabilistic graphical models
- Probabilistic temporal models
- Probabilistic logics
- Markov decision processes
- Reinforcement learning
- Deep reinforcement learning
- Machine learning
- Advanced topics of AI