

# **Artificial Intelligence - INFOF311**

## **Organisation**

**Instructor : Tom Lenaerts**

Introduce you to the basics of AI, theories and algorithms

## 4 main themes :

Part 1 : Search and planning (uninformed and informed search, local search, game and adversarial search, ...)

Part 2: Probabilistic reasoning (Bayesian network, hidden Markov models,...)

Part 3: Decision making with uncertainty (MDP, reinforcement learning, ...)

Part 4: Machine learning (naïve bayes, perceptrons, regression, neural networks, ...)

**New course = 24h theory, 24h exercises and 60h projects (5 ECTS)**

Two sessions per week:

Monday 12-14

Tuesday 10-12



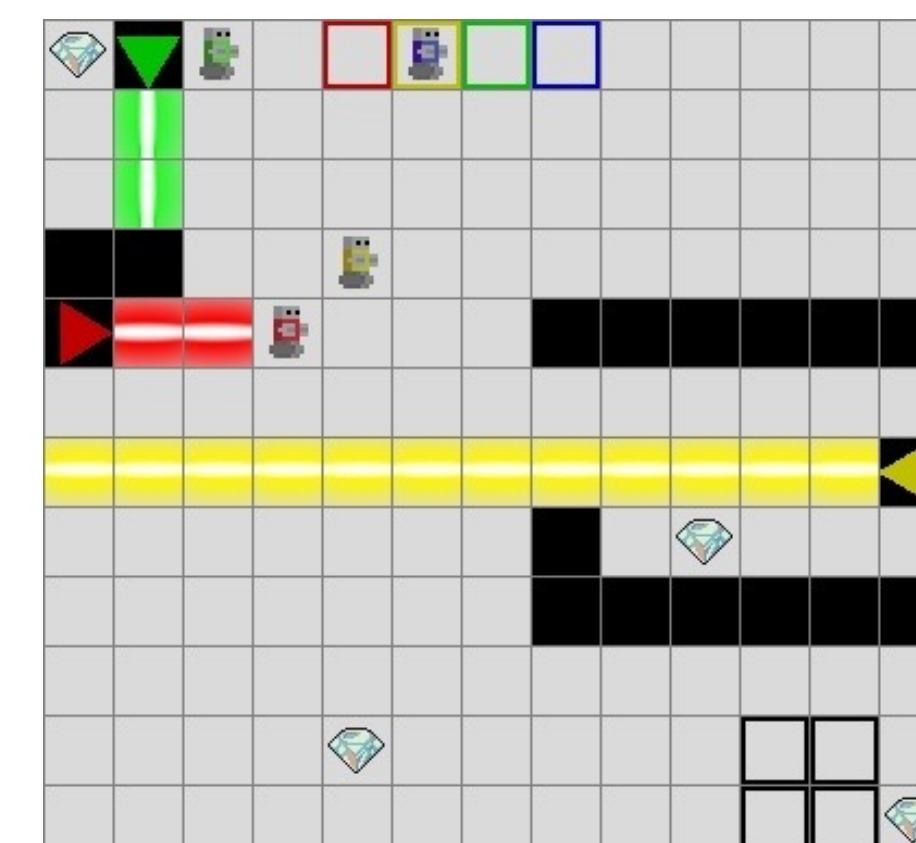
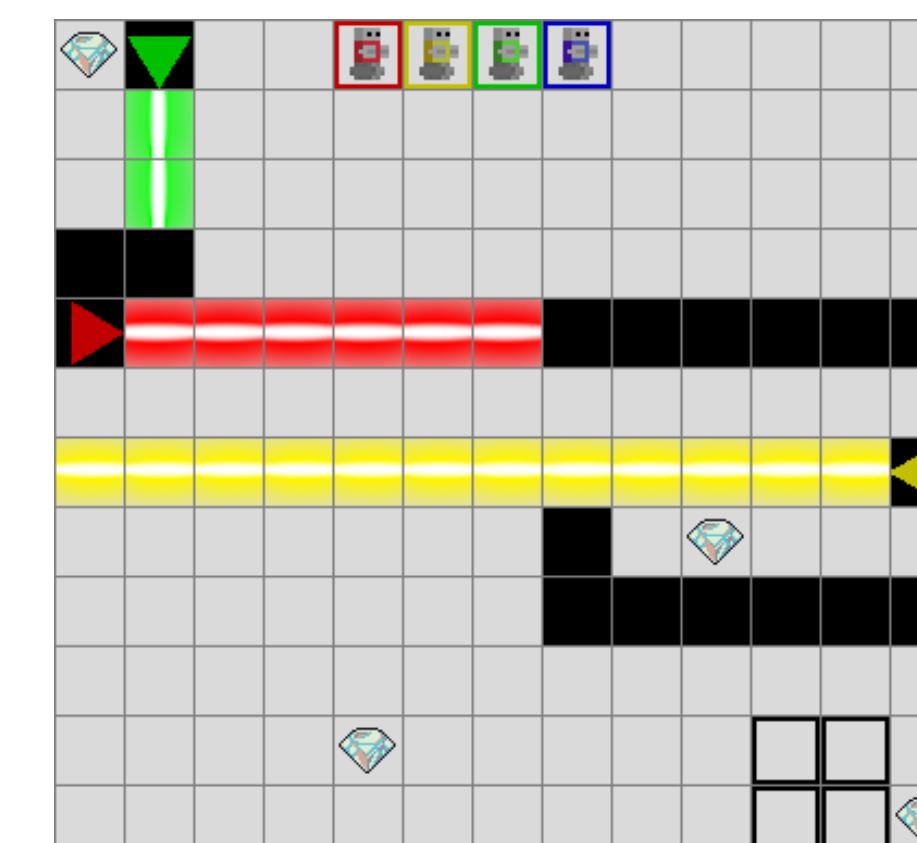
[Check calendar for  
location and exact  
dates/times](#)

Each session = 1 hour theory + 1 hour questions and exercises

5 projects practicing the algorithms discussed in the course

(Strict) Deadlines on UV

Laser environment (python)



# Calendrier provisoire

	Lundi	EX	Mardi	EX	Projet
18/09/2023	INTRO		pas de cours		
25/09/2023	SEARCH		INFORMED		P-SEARCH
02/10/2023	pas de cours		pas de cours		
09/10/2023	LOCAL		GAMES 1		P-ADV
16/10/2023	GAMES 2		PROB		
23/10/2023	BAYES 1		BAYES 2		
30/10/2023	pas de cours		pas de cours		P-BAYES
06/11/2023	BAYES 3		BAYES4		
13/11/2023	HMM		FILTER		
20/11/2023	DEC NW		MDP1		P-RL
27/11/2023	MDP2		RL1		
04/12/2023	RL2		ML		
11/12/2023	PERCEP		NN1		P-ML
18/12/2023	NN2		pas de cours		

## Scores for this course

*5 projects, each counting the same*

**40% of the final score**

Topics ; search, adversarial search, Bayesian agents, learning agents and machine learning agents)

*Theory and exercises exam*

**60% of the final score**

See examples in exercises book

**In you fail one of them (less than 10/20) , that score will count as the final score**



All information provided via “Univeristé Virtuelle”

Schedule (and updates)

Slides and exercises (added incrementally)

Projects and support software (python)

General course information

Announcements → **Check your email!**

## 5 individual projects :

Before 1<sup>st</sup>  
buffer week  
(30/10/2023)

One project on search and planning  
One project on adversarial search and game play

One project on Bayesian networks and agents

after 1<sup>st</sup> buffer  
week  
(30/10/2023)

One project on reinforcement learning  
One project on Machine Learning

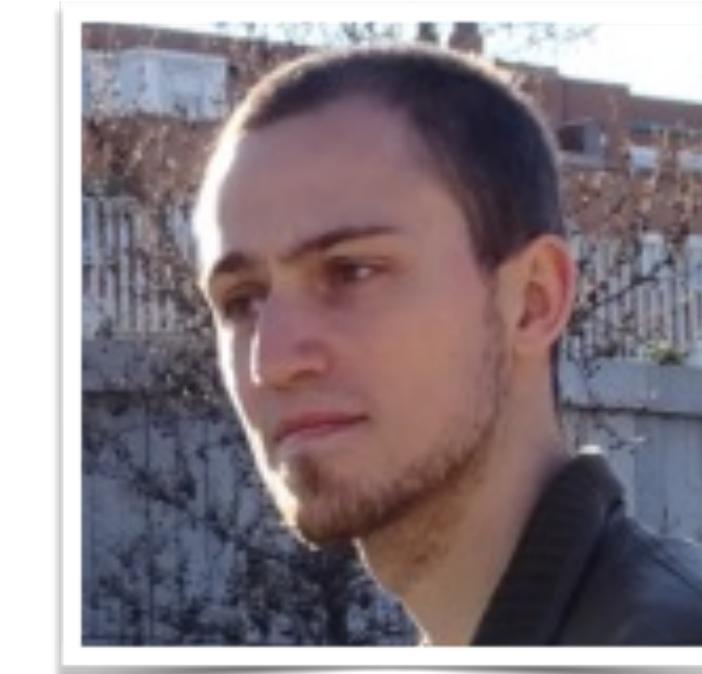
**Plagiarism checks will be done.**

# Course Staff

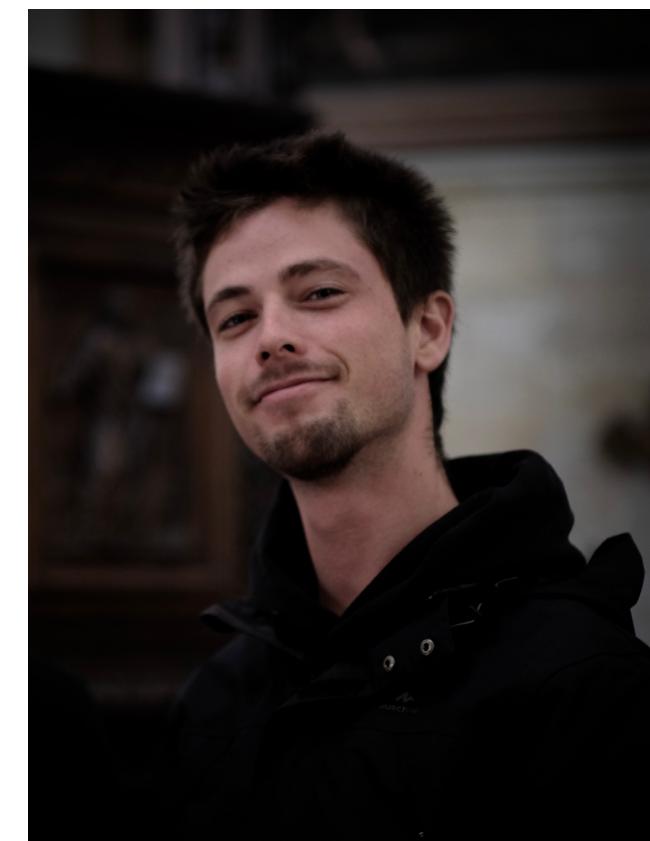
Tom Lenaerts



Yannick Molinghen



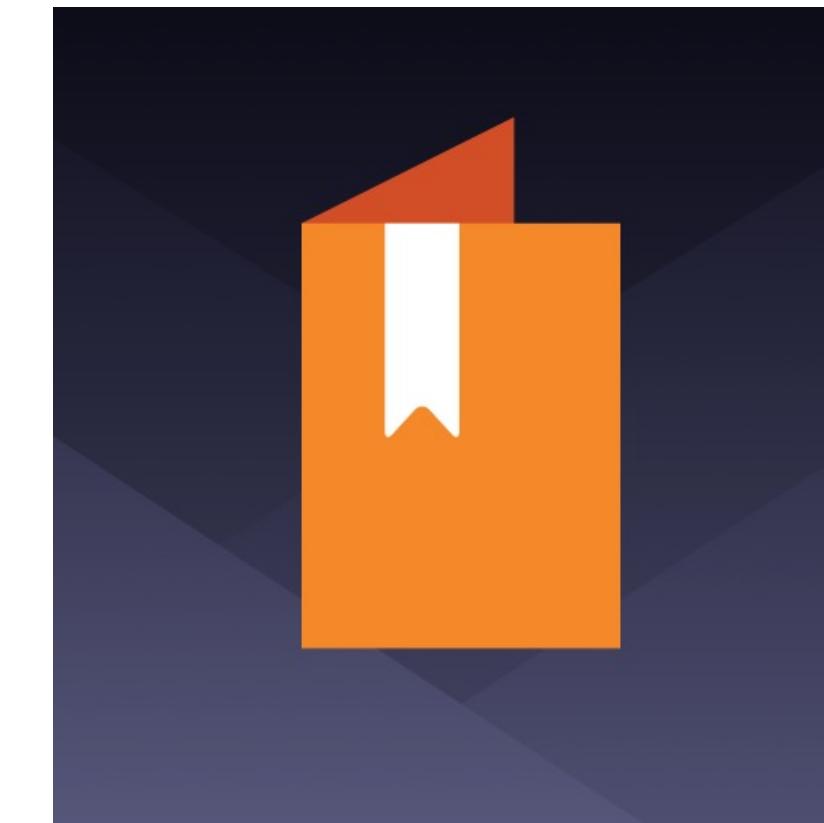
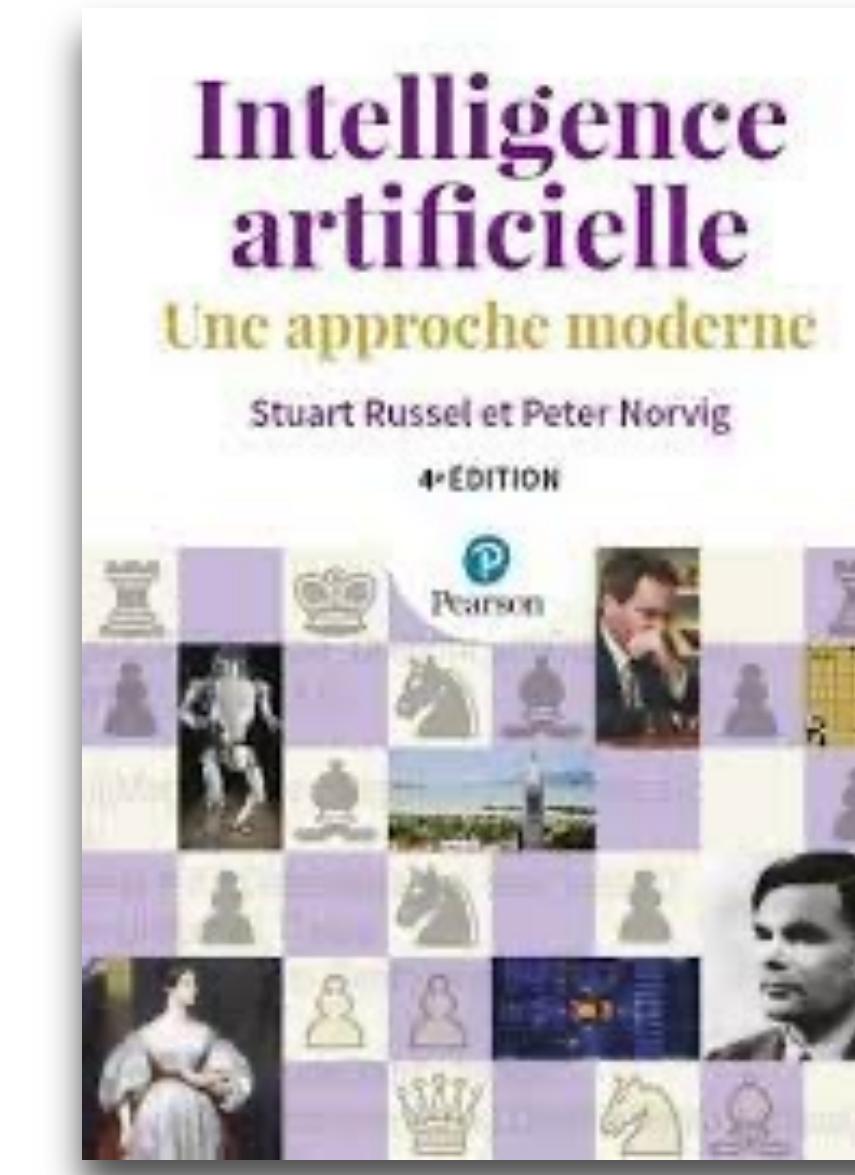
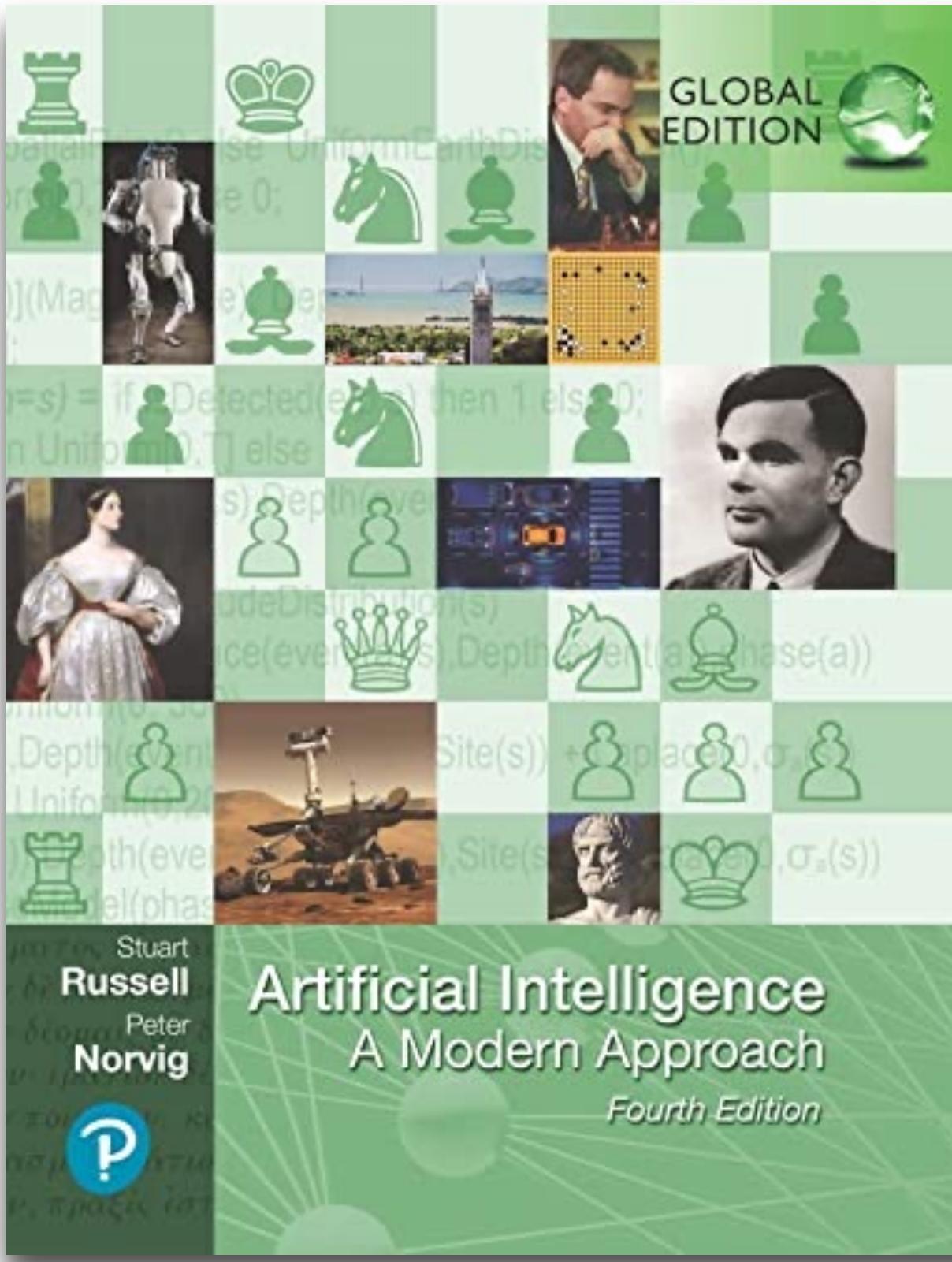
Pascal Tribel



Web; ULB machine learning group - [mlg.ulb.ac.be](http://mlg.ulb.ac.be)

**Contact session on Monday right after the theory and exercises**

# Textbook



VitalSource®

Russell & Norvig, AI: A modern approach, 4th (**global**) edition  
(available in most online bookshops or ebook via bookshelf -  
<https://www.pearson.fr/book/?gcoi=27440100705580>)

5 copies available in the ULB Science and engineering library

# **Artificial Intelligence - INFOF311**

## **Introduction**

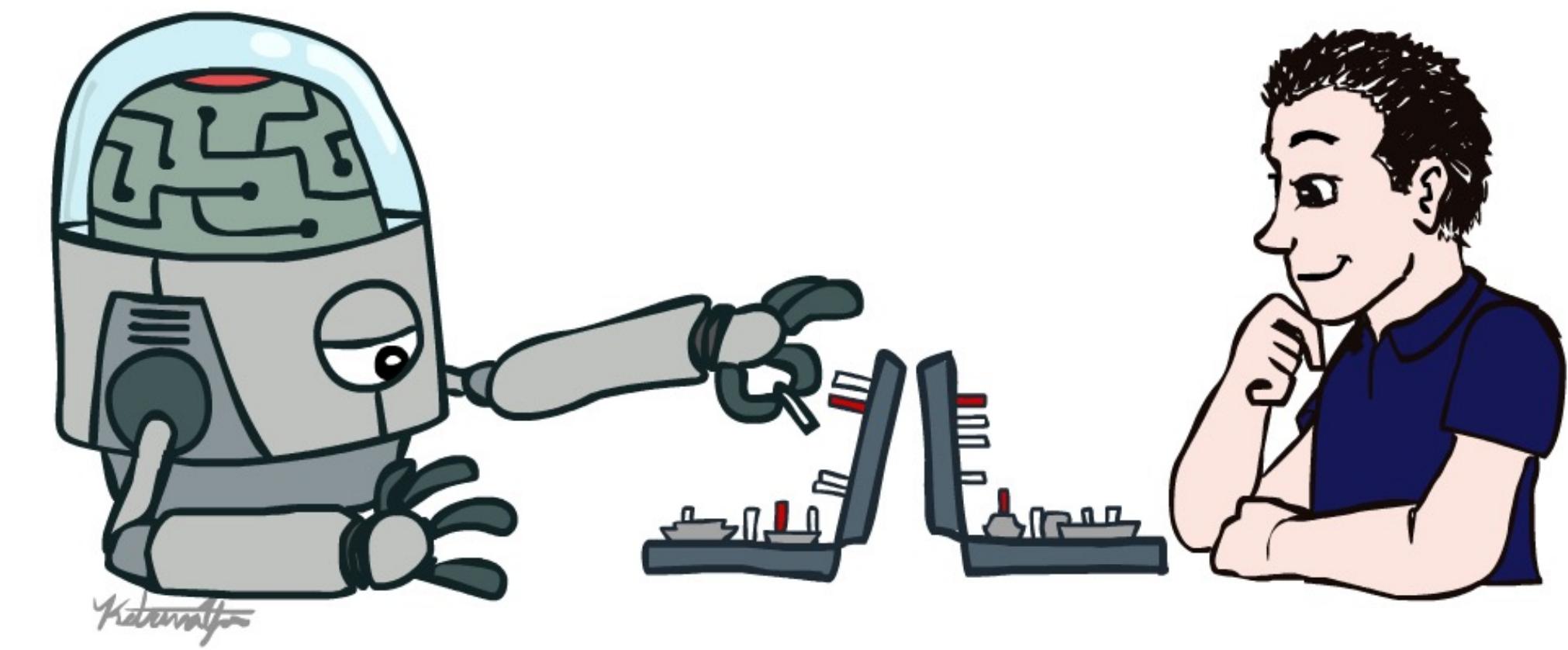
**Instructor : Tom Lenaerts**

# Acknowledgement

We thank Stuart Russell for his generosity in allowing us to use the slide set of the UC Berkeley Course CS188, Introduction to Artificial Intelligence. These slides were created by Dan Klein, Pieter Abbeel and Anca Dragan for CS188 Intro to AI at UC Berkeley. All CS188 materials are available at <http://ai.berkeley.edu>.]



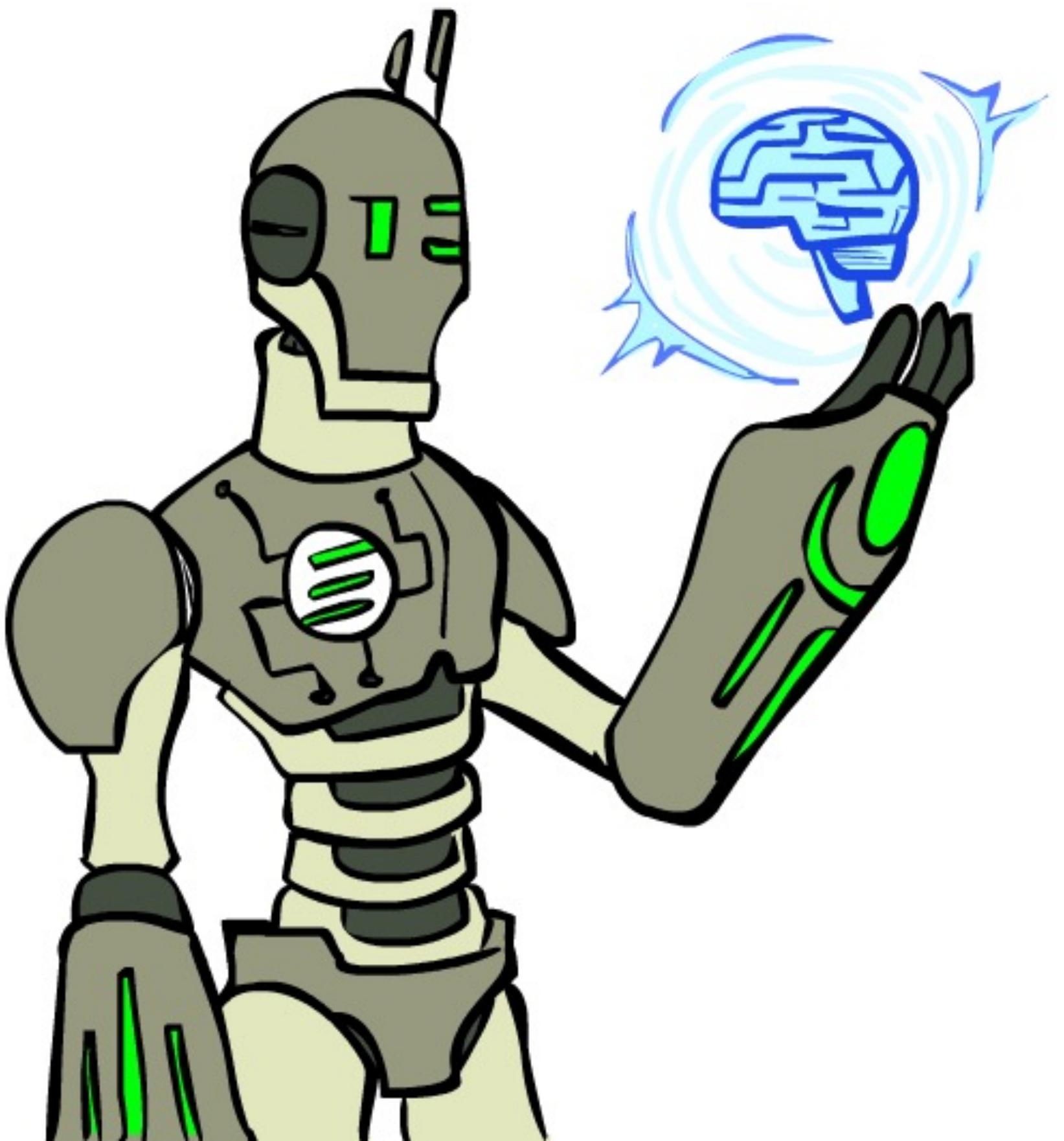
Center for  
Human-Compatible  
Artificial  
Intelligence



The slides for INFOF311 are slightly modified versions of the slides of the spring and summer CS188 sessions in 2021 and 2022

# First steps ...

- What is artificial intelligence ?
- Where are we and how did we get here ?
- How to think about the design of AI systems ?



# AI in the movies ...



# AI in the news ...

**Futurism**

FUTURISM | 7. 17. 17 by DOM GALEON

## Elon Musk: Unregulated AI Could Be The “Biggest Risk We Face as a Civilization”

"AI is a rare case where I think we need to be proactive in regulating it instead of reacting to it."

### Artificial Intelligence, A Threat? Top 10 Dangerous Traits of AI

Find out the risks of artificial intelligence by taking a look into the dangerous traits of AI.

ARATRIKA | Article Updated: October 5, 2021 | COMMENTS OFF

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14

15 NOV 2021 RESEARCH & INNOVATION

## New Survey: Americans Think AI Is a Threat to Democracy, Will Become Smarter than Humans and Overtake Jobs, Yet Believe its Benefits Outweigh its Risks

Stevens Institute of Technology research finds Americans embracing a larger role for AI in every aspect of life

SHARE THIS STORY [Facebook](#) [Twitter](#)



INNOVATION

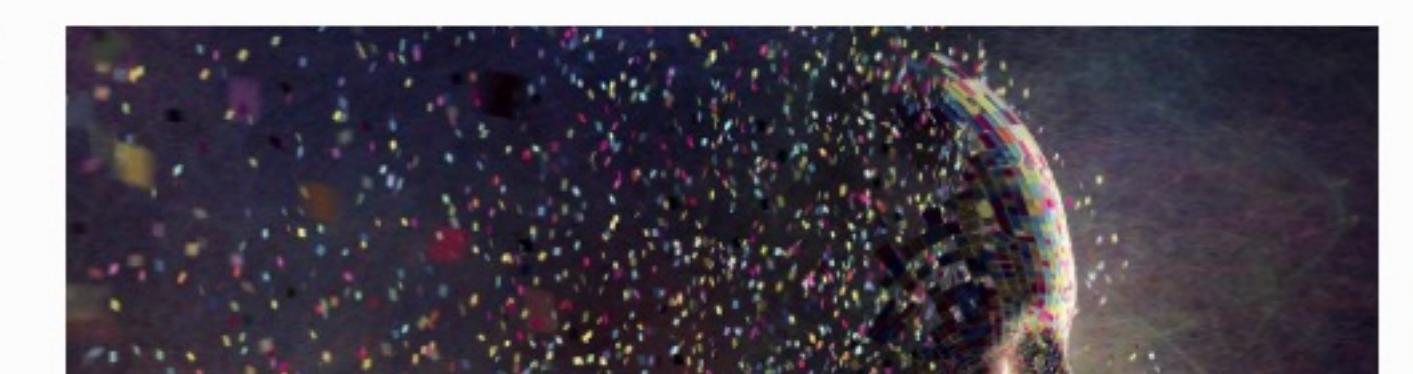
## What You Need To Know About The New Threat: Poisoned AI



John Giordani Forbes Councils Member  
Forbes Technology Council  
COUNCIL POST | Membership (Fee-Based)

May 23, 2022, 07:15am EDT

f John Giordani has extensive experience in cybersecurity and information assurance. He is Chief Information Security Officer at NCHENG LLP.



Deep Blue computer beats world chess champion - archive, 1996

Ai and games ...

12 February 1996: IBM supercomputer makes chess history by beating Garry Kasparov, the world's best chess player



## IBM's Watson Jeopardy Computer Shuts Down Humans in Final Game > Silicon prevails in men vs. machine challenge

BY ERICO GUIZZO | 17 FEB 2011 | 4 MIN READ |

## 'I'm in shock!' How an AI beat the world's best human at Go



TECHNOLOGY 9 March 2016

By Mark Zastrow



## How A.I. Conquered Poker

Good poker players have always known that they need to maintain a balance between bluffing and playing it straight. Now they can do so perfectly.

Home > News > RTS > StarCraft 2

## Blizzard will show off Google's Deepmind AI in StarCraft 2 later this week

published January 22, 2019

Blizzard launched the artificial intelligence project in 2016.



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# Ai race ???

# United Kingdom Plans \$1.3 Billion Artificial Intelligence Push

BY JONATHAN VANIAN

April 26, 2018, 1:01 AM GMT+2

TECHNOLOGY NEWS MARCH 29, 2018 / 3:36 PM / UPDATED 4 YEARS AGO

## France to spend \$1.8 billion on AI to compete with U.S., China

French President Emmanuel Macron delivers a speech during the Artificial Intelligence for Humanity event in Paris, France, March 29, 2018. Etienne Laurent/Pool via Reuters

By Mathieu Rosemain, Michel Rose

4 MIN READ



## China's Got a Huge Artificial Intelligence Plan

- Priorities are intelligent robotics, vehicles, virtual reality
- AI seen contributing up to \$15.7 trillion worldwide by 2030

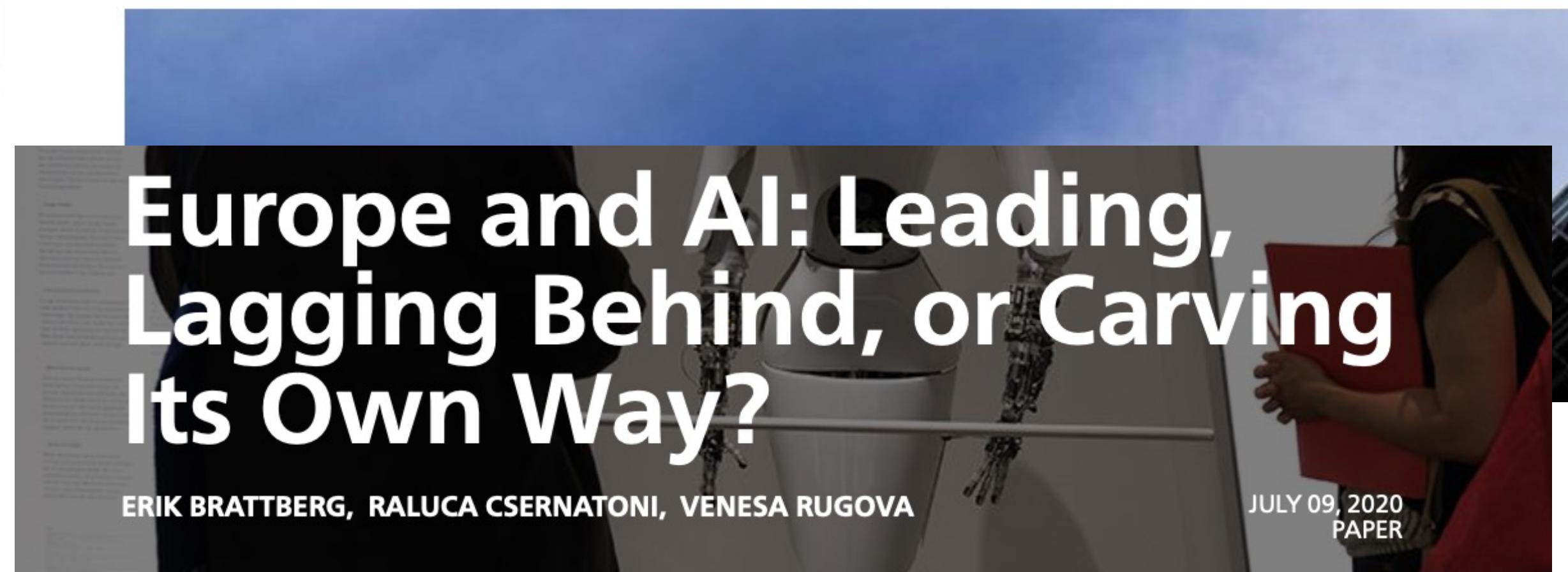
## EU to invest 1.5 billion euros in AI to catch up with US, Asia

By Julia Fioretti

3 MIN READ



BRUSSELS (Reuters) - The European Commission will boost its investment in artificial intelligence by about 70 percent to 1.5 billion euros (\$1.83 billion) by 2020 to catch up with Asia and the United States, which are each investing at least three times more than Europe.



## Europe and AI: Leading, Lagging Behind, or Carving Its Own Way?

ERIK BRATTBERG, RALUCA CSERNATONI, VENESA RUGOVA

JULY 09, 2020 PAPER

For its AI ecosystem to thrive, Europe needs to find a way to protect its research base, encourage governments to be early adopters, foster its startup ecosystem, expand international links, and develop AI technologies as well as leverage their use efficiently.

FULL TEXT (PDF)



# AI in Belgium ...

## AI4Belgium

Artificial Intelligence by and for people

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AI 4 Belgium is a grassroots community that enables Belgian people and organizations to capture the opportunities of AI while facilitating the ongoing transition responsibly. This coalition brings together AI key-players from public sector, private sector, academia and civil society. AI 4 Belgium has the ambition to position Belgium, including its regions, in the European AI landscape.

Download the report

Discover the survey

Join AI4Belgium



## FARI an AI Institute for the Common Good and Brussels - NextGenerationEU

PUBLIÉ LE 14 JANVIER 2022 – MIS À JOUR LE 14 JANVIER 2022

**FARI - AI Institute for the Common Good was created by the Vrije Universiteit Brussel and the Université libre de Bruxelles. It was launched in 2021 and received the support of the NextGenerationEU. This will help fund activities related to AI, Data and Robotics for and with Brussels, its citizens, administrations, companies and organizations.**

This two-hour online event will welcome international experts to present what using these technologies for Common Good can mean, and local decision-makers will also share their views on what could be their contribution for the Brussels Region.

## Flanders earmarks EUR 30 million for AI development

Flanders will be earmarking another 30 million euros for AI research, industry application and educational initiatives. The government of Flanders will mainly support AI research, industry application and educational initiatives. The region is in pole position when it comes to innovation in artificial intelligence. The government of Flanders will mainly support AI educational initiatives.

## AI FLANDERS

BUILDING OUR DIGITAL FUTURE



## Economie@Wallonie

Compétitivité & Innovation

[Accueil](#) » Le Gouvernement de Wallonie valide le projet « ARIAC by DigitalWallonia4.ai » pour une intelligence artificielle de confiance

PORTEAIL DES CLUSTERS

Le Gouvernement de Wallonie valide le projet « ARIAC by DigitalWallonia4.ai » pour une intelligence artificielle de confiance



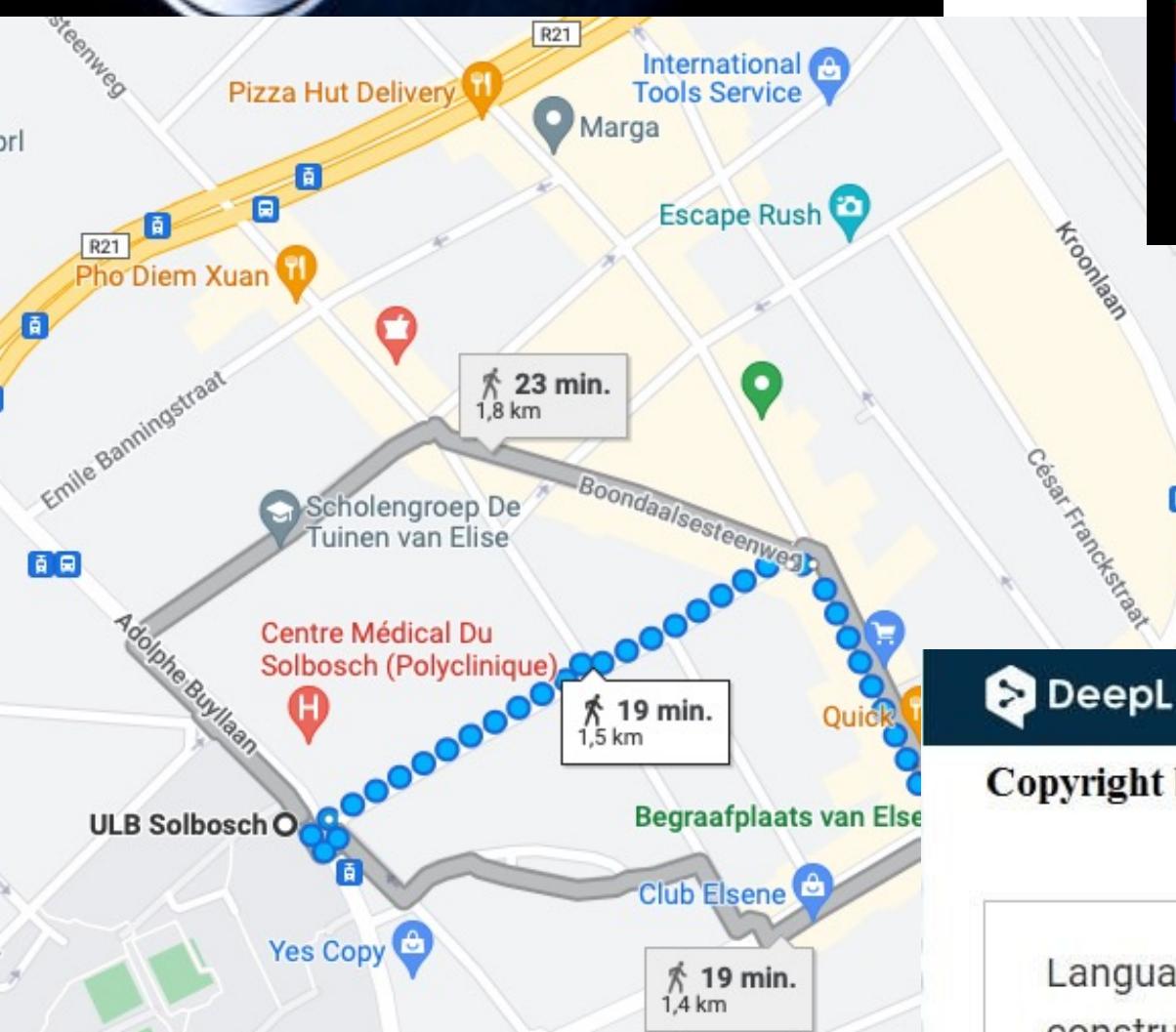
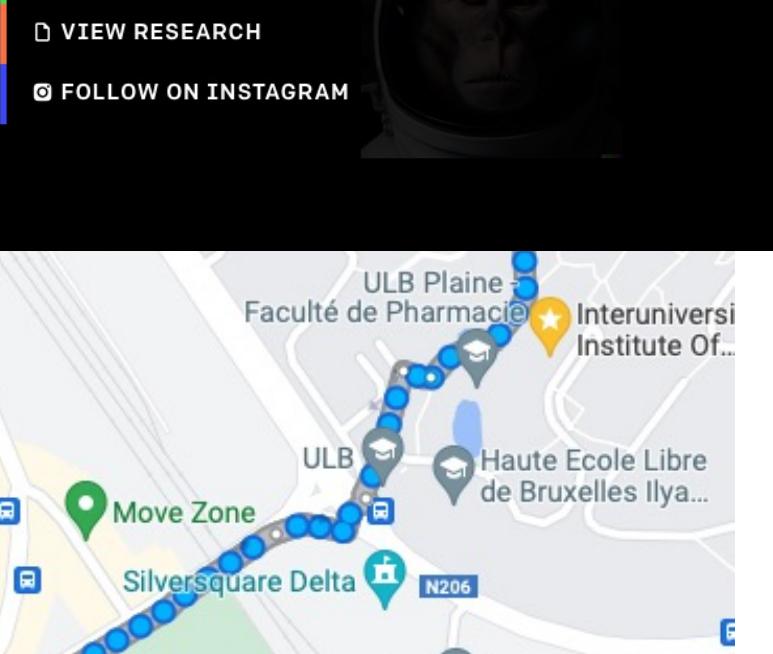
## TRAIL

TRUSTED AI LABS  
BY DIGITALWALLONIA4.AI / SPW-RECHERCHE

# Current AI...

# DALL·E 2

DALL·E 2 is a new AI system that can create realistic images and art from a description in natural language.



DeepL

Copyright by DeepL

English

Languages are a fascinating construct that will never be fully understood.

Translate document

Translate into French

Les langues sont une construction fascinante qui sera jamais pleinement

**OpenAI GPT-3**

[www.analyticssteps.com](http://www.analyticssteps.com)



# Current AI...



# What is AI?

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The science of making machines that:

# Rational Decisions

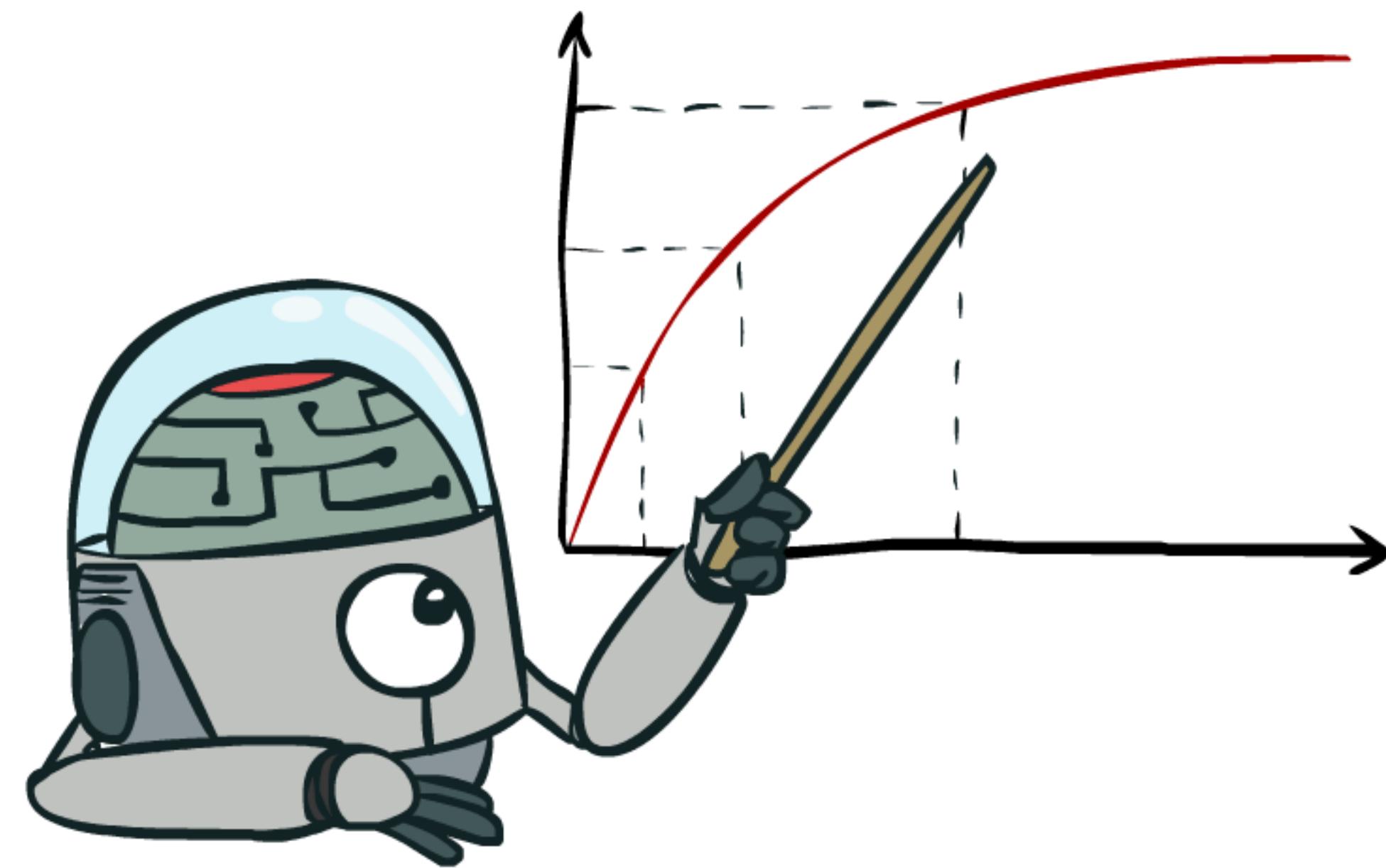
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- We'll use the term **rational** in a very specific, technical way:
  - Rational: maximally achieving pre-defined goals
  - Rationality only concerns what decisions are made (not the thought process behind them)
  - Goals are expressed in terms of the **utility** of outcomes
  - Being rational means **maximizing your expected utility**

A better title for this course would be:

**Computational Rationality**

# Maximize Your Expected Utility

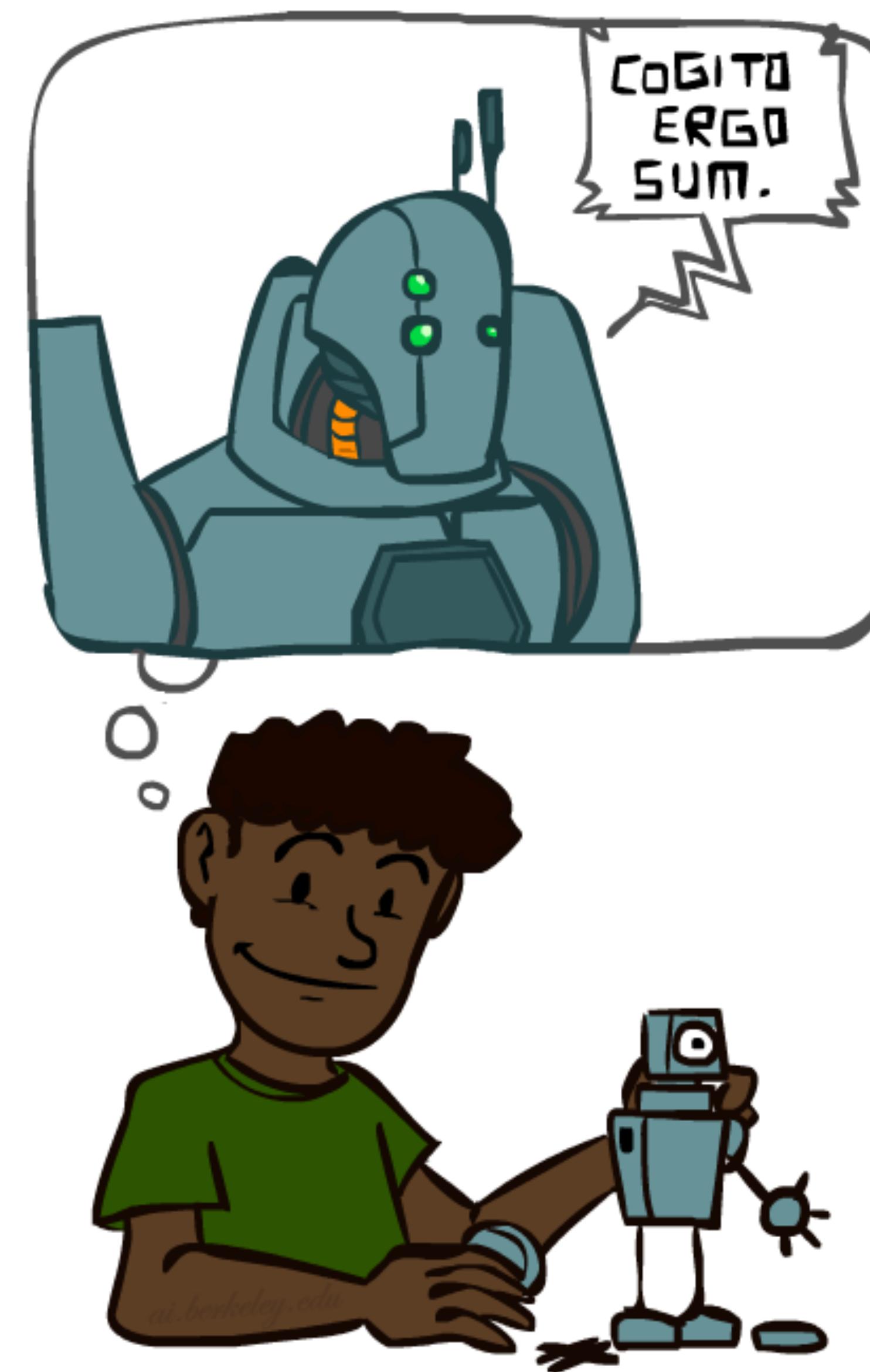


# What About the Brain?

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- 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!
- “Brains are to intelligence as wings are to flight”
- Lessons learned from the brain: memory and simulation are key to decision making

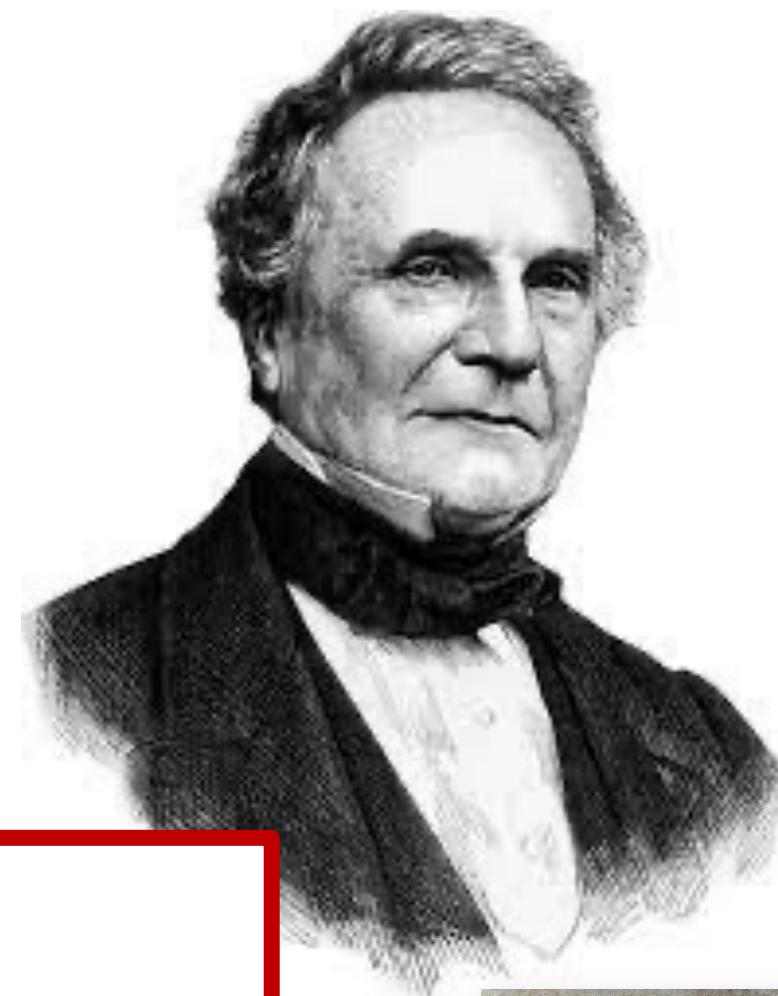
# A short history of AI



- Prehistory:
  - **Philosophy** (reasoning, planning, learning, science, automation)
  - **Mathematics** (logic, probability, optimization)
  - **Neuroscience** (neurons, adaptation)
  - **Economics** (rationality, game theory)

Aristotle: For if every instrument could accomplish its own work, obeying or anticipating the will of others . . . if, in like manner, the shuttle would weave and the plectrum touch the lyre without a hand to guide them, chief workmen would not want servants, nor masters slaves

- Near miss (1842):
  - Babbage design for universal machine
  - Lovelace: “a thinking machine” for “all subjects in the universe.”

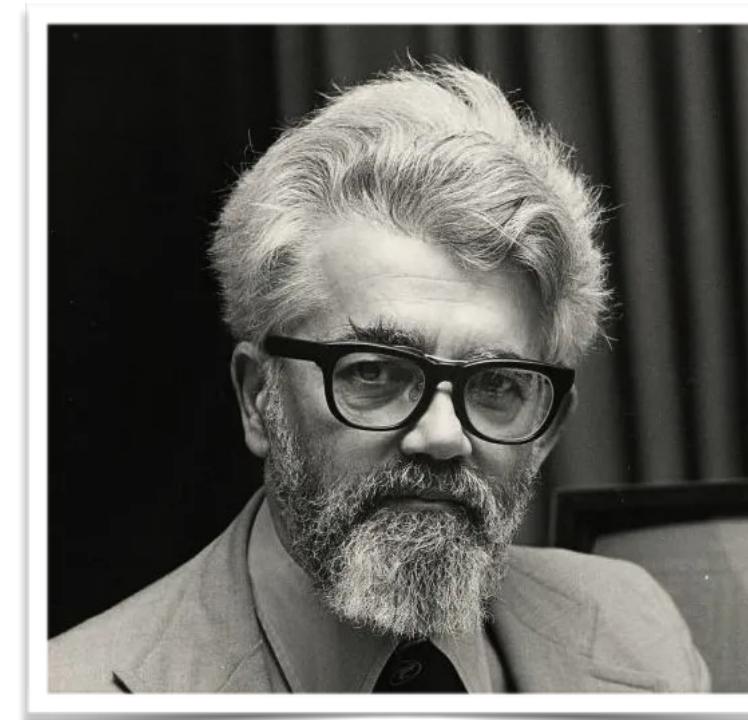


For details see section 1.2

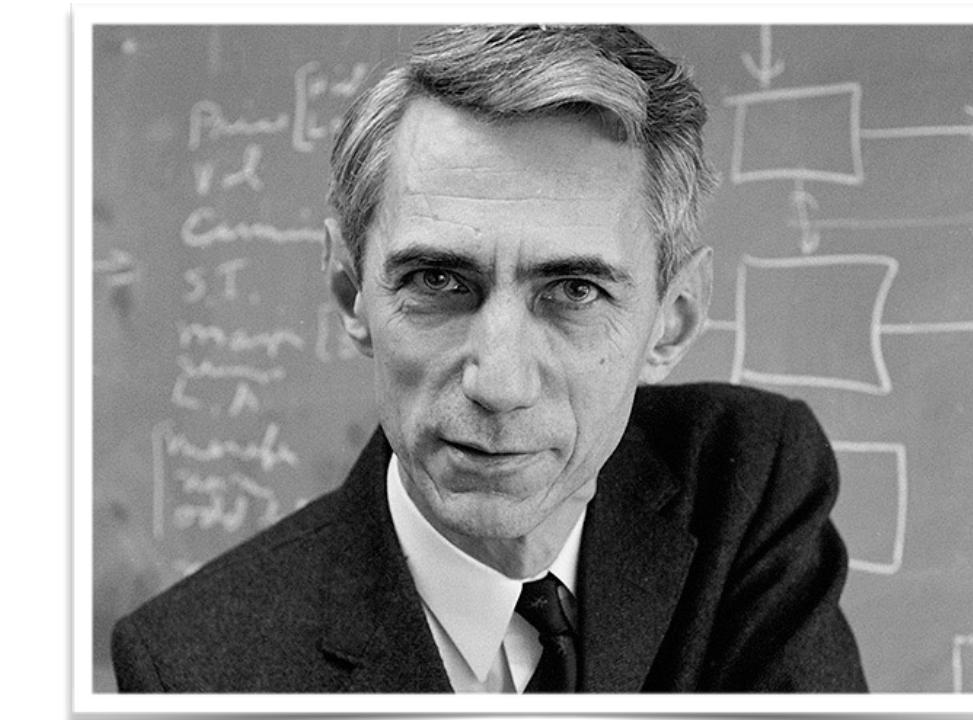
## Official birth year : 1956 Dartmouth workshop

*“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 if we work on it together for a summer.”*

Proposed by ...

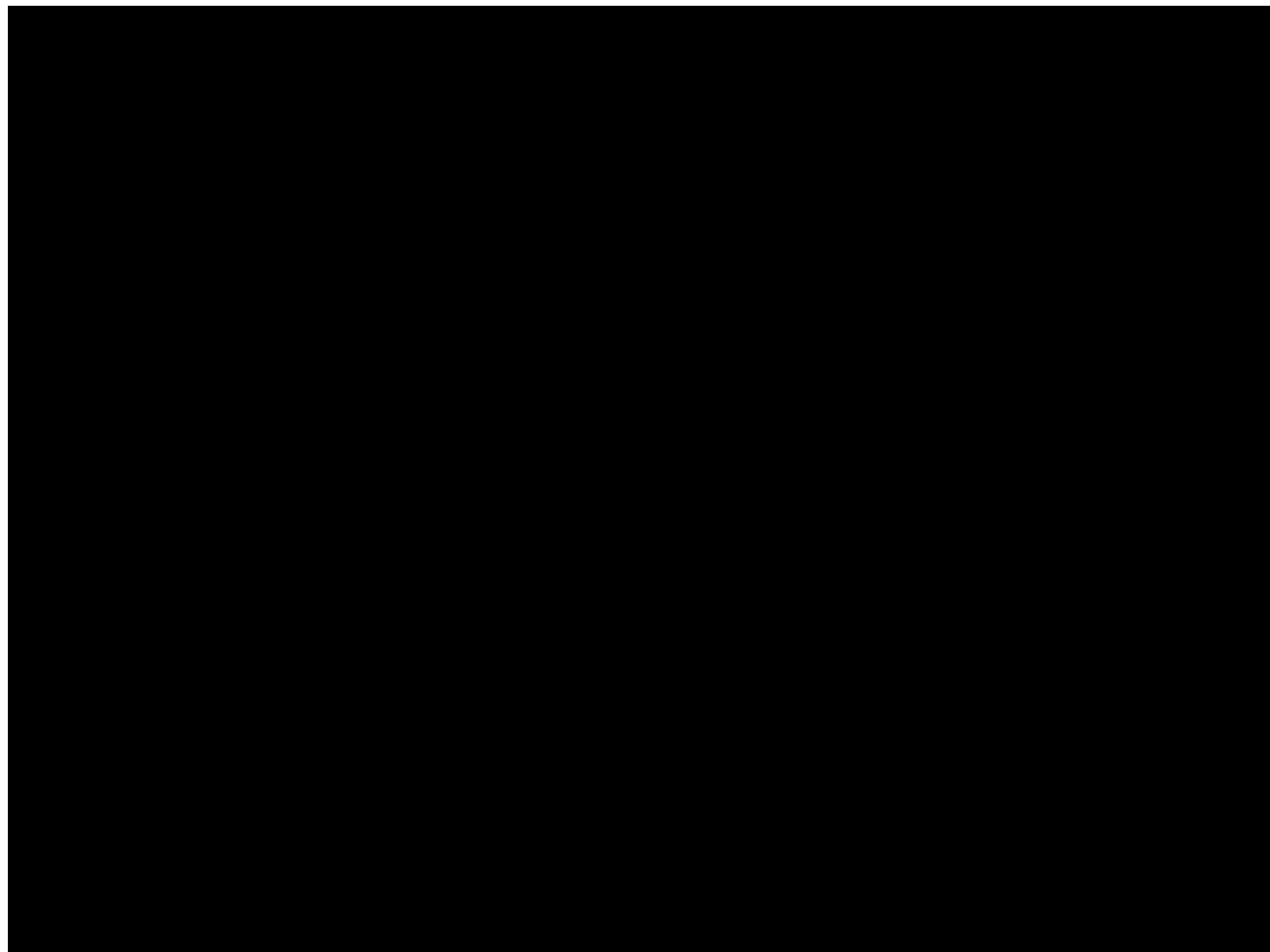


John McCarthy



Claude Shannon

# Early excitement



# A short history of AI

## 1940-1950: Early days

1943: McCulloch & Pitts: Boolean circuit model of brain  
1950: Turing's "Computing Machinery and Intelligence"

## 1950–70: Excitement: Look, Ma, no hands!

1950s: Early AI programs: chess, checkers (RL), theorem proving  
1956: Dartmouth meeting: "Artificial Intelligence" adopted  
1965: Robinson's complete algorithm for logical reasoning

## 1970–90: Knowledge-based approaches

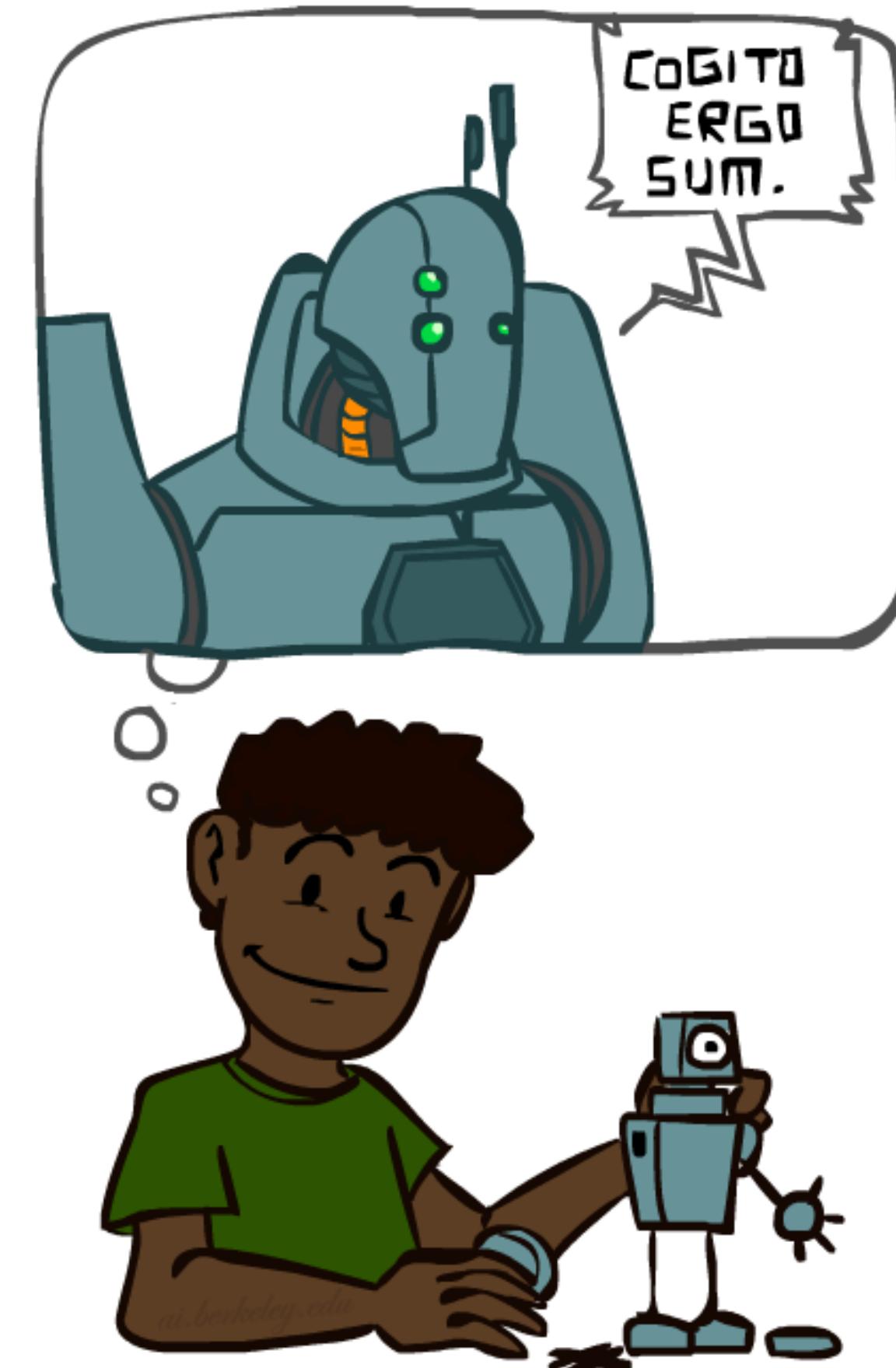
1969–79: Early development of knowledge-based systems  
1980–88: Expert systems industry booms  
1988–93: Expert systems industry busts: "AI Winter"

## 1990– 2012: Statistical approaches + subfield expertise

Resurgence of probability, focus on uncertainty  
General increase in technical depth  
Agents and learning systems... "AI Spring"?

## 2012– \_\_\_: Excitement: Look, Ma, no hands again?

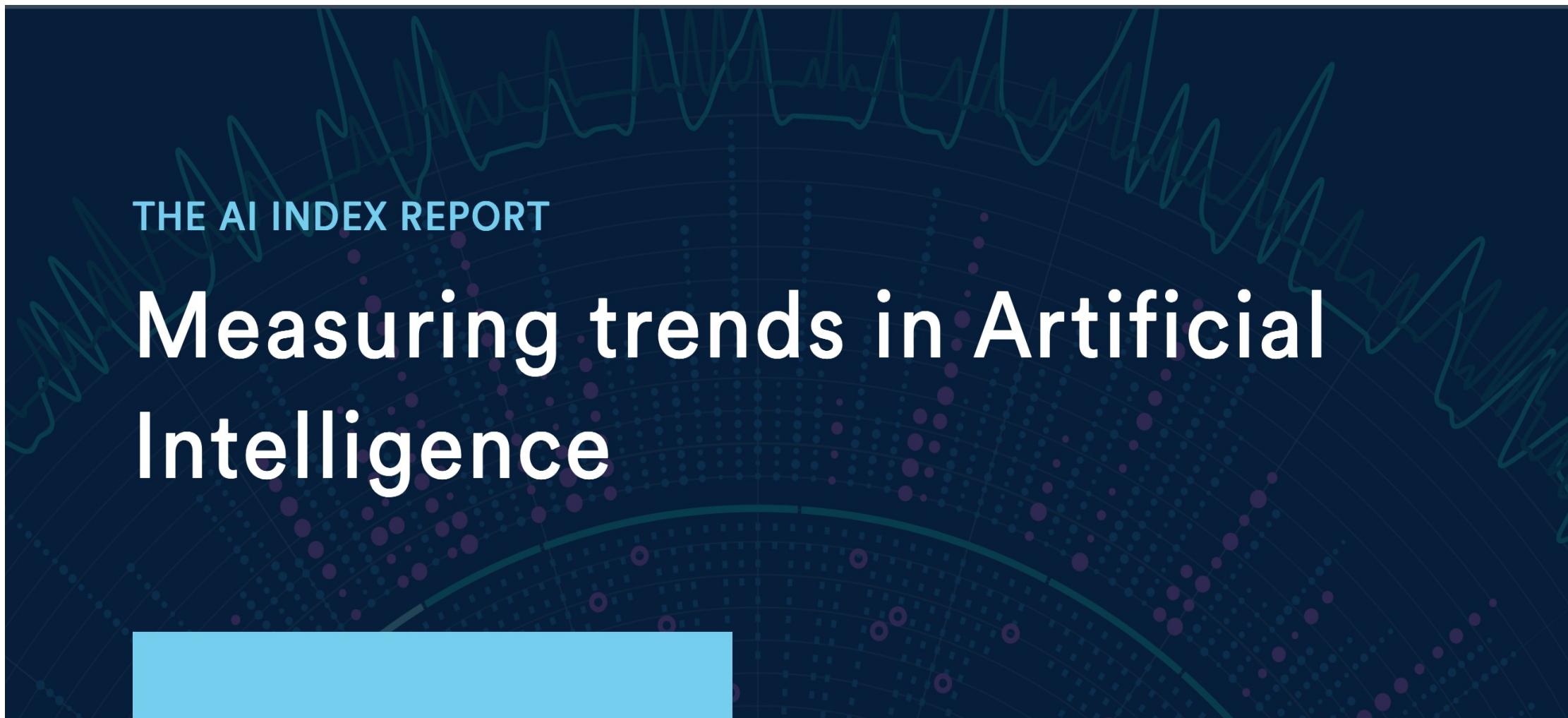
Big data, big compute, deep learning  
AI used in many industries



For details see section 1.3

# State of the art

For details see section 1.4



## AI INDEX ANNUAL REPORT

### Welcome to the 2023 AI Index Report

[DOWNLOAD THE FULL REPORT](#)

[DOWNLOAD INDIVIDUAL CHAPTERS](#)

[ACCESS THE PUBLIC DATA](#)

The AI Index is an independent initiative at the Stanford Institute for Human-Centered Artificial Intelligence (HAI), led by the AI Index Steering Committee, an interdisciplinary group of experts from across academia and industry. The annual report tracks, collates, distills, and visualizes data relating to artificial intelligence, enabling decision-makers to take meaningful action to advance AI responsibly and ethically with humans in mind.

The AI Index collaborates with many different organizations to track progress in artificial intelligence. These

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

## TOP TAKEAWAYS

### Industry races ahead of academia.

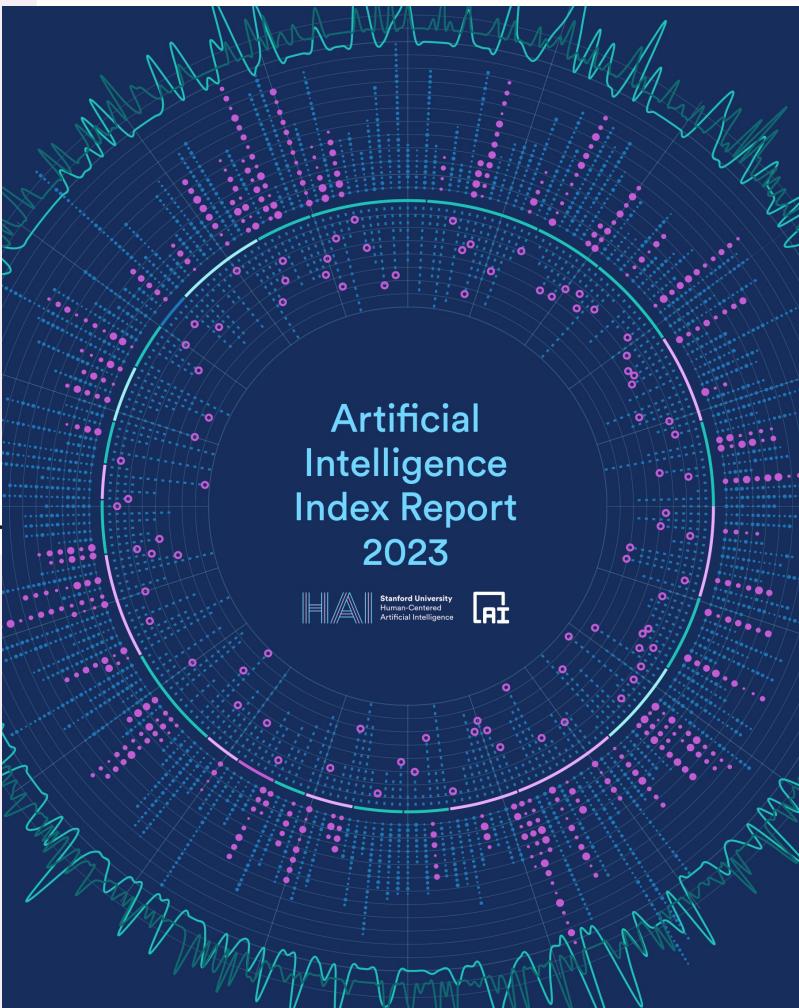
Until 2014, most significant machine learning models were released by academia. Since then, industry has taken over. In 2022, there were 32 significant industry-produced machine learning models compared to just three produced by academia. Building state-of-the-art AI systems increasingly requires large amounts of data, compute, and money, resources that industry actors inherently possess in greater amounts compared to nonprofits and academia.

### Performance saturation on traditional benchmarks.

AI continued to post state-of-the-art results, but year-over-year improvement on many benchmarks continues to be marginal. Moreover, the speed at which benchmark saturation is being reached is increasing. However, new, more comprehensive benchmarking suites such as BIG-bench and HELM are being released.

### AI is both helping and harming the environment.

New research suggests that AI systems can have serious environmental impacts. According to Luccioni et al., 2022, BLOOM's training run emitted 25 times more carbon than a single air traveler on a one-way trip from New York to San Francisco. Still, new reinforcement learning models like BCOOLER show that AI systems can be used to optimize energy usage.



### The world's best new scientist ... AI?

AI models are starting to rapidly accelerate scientific progress and in 2022 were used to aid hydrogen fusion, improve the efficiency of matrix manipulation, and generate new antibodies.

### The number of incidents concerning the misuse of AI is rapidly rising.

According to the AIAAC database, which tracks incidents related to the ethical misuse of AI, the number of AI incidents and controversies has increased 26 times since 2012. Some notable incidents in 2022 included a deepfake video of Ukrainian President Volodymyr Zelenskyy surrendering and U.S. prisons using call-monitoring technology on their inmates. This growth is evidence of both greater use of AI technologies and awareness of misuse possibilities.

### The demand for AI-related professional skills is increasing across virtually every American industrial sector.

Across every sector in the United States for which there is data (with the exception of agriculture, forestry, fishery and hunting), the number of AI-related job postings has increased on average from 1.7% in 2021 to 1.9% in 2022. Employers in the United States are increasingly looking for workers with AI-related skills.

### For the first time in the last decade, year-over-year private investment in AI decreased.

Global AI private investment was \$91.9 billion in 2022, which represented a 26.7% decrease since 2021. The total number of AI-related funding events as well as the number of newly funded AI companies likewise decreased. Still, during the last decade as a whole, AI investment has significantly increased. In 2022 the amount of private investment in AI was 18 times greater than it was in 2012.

### While the proportion of companies adopting AI has plateaued, the companies that have adopted AI continue to pull ahead.

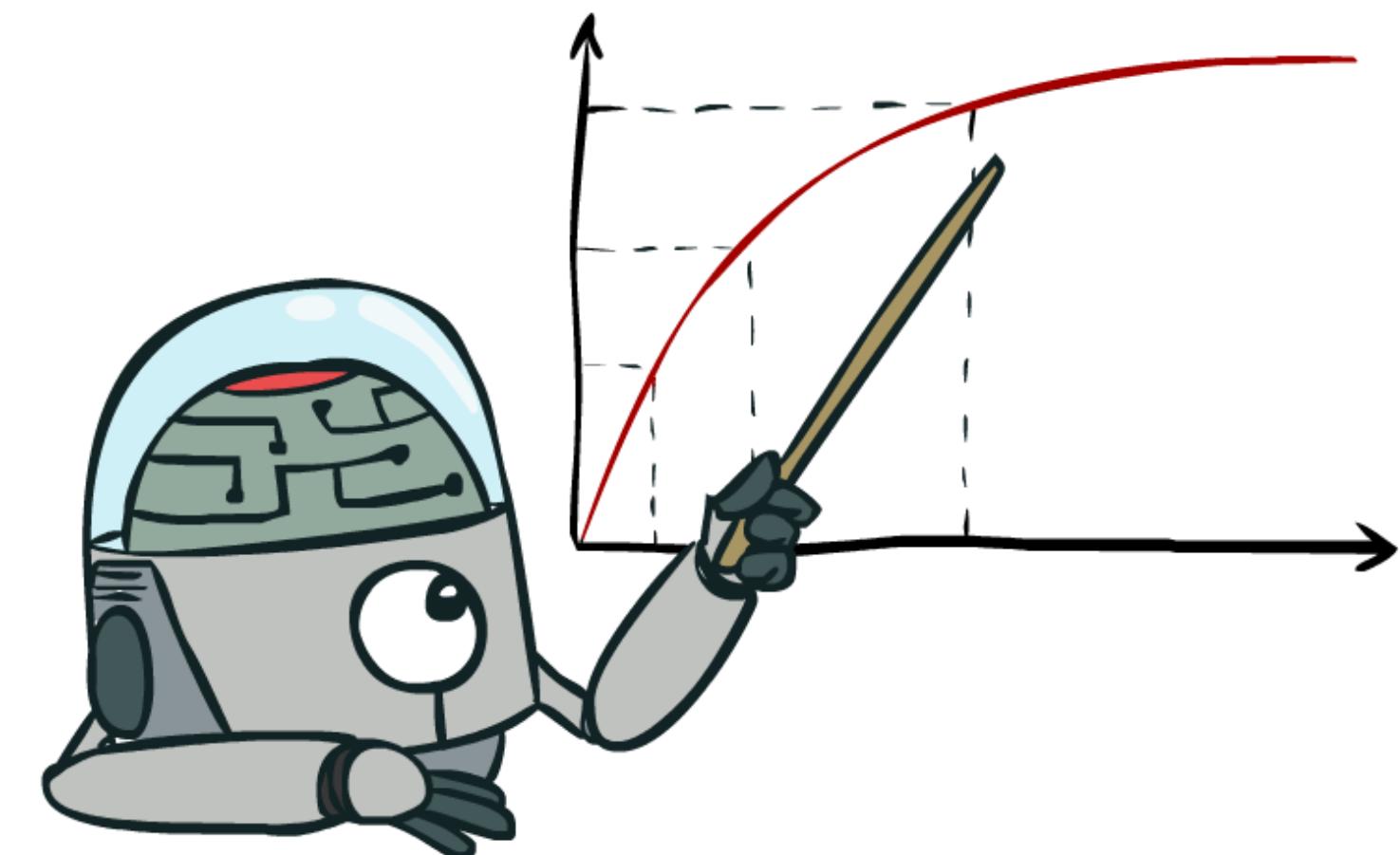
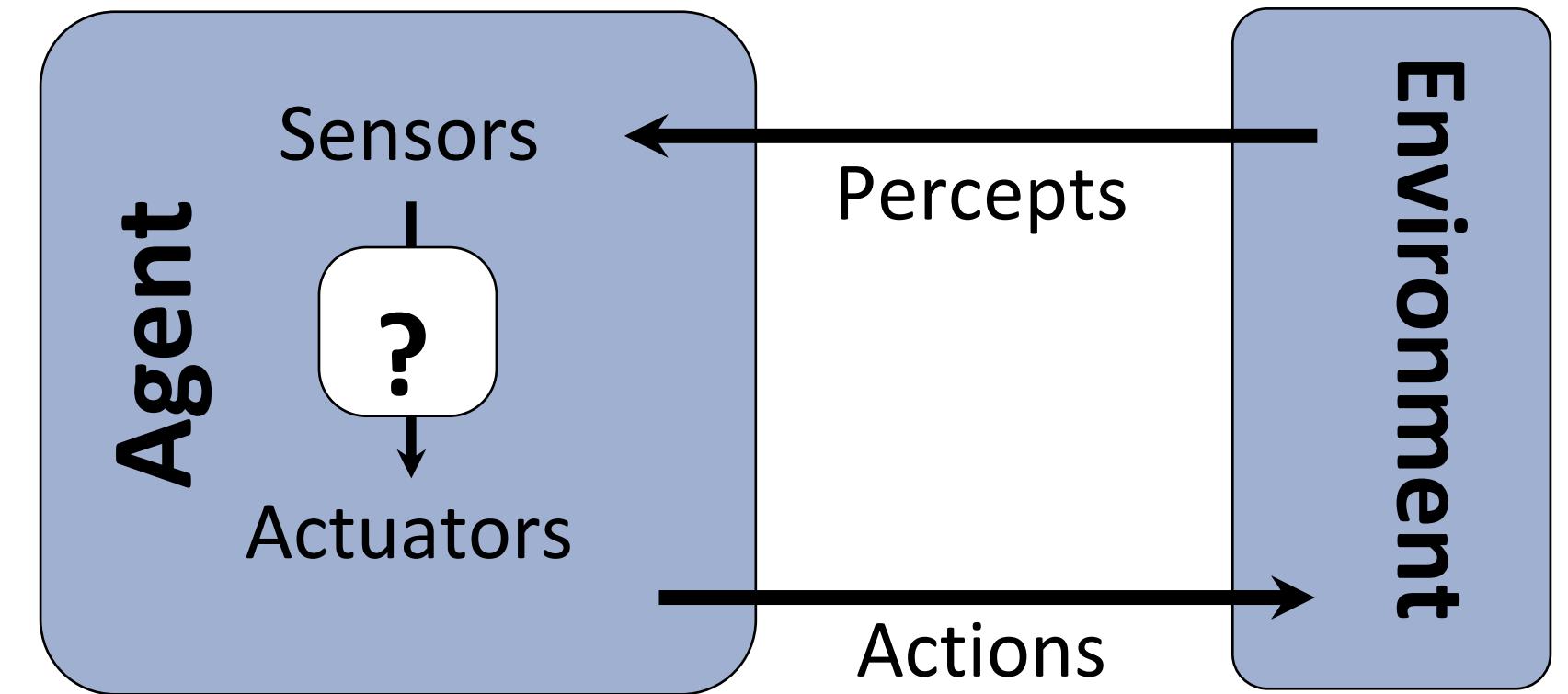
The proportion of companies adopting AI in 2022 has more than doubled since 2017, though it has plateaued in recent years between 50% and 60%, according to the results of McKinsey's annual research survey. Organizations that have adopted AI report realizing meaningful cost decreases and revenue increases.

### Chinese citizens are among those who feel the most positively about AI products and services. Americans ... not so much.

In a 2022 IPSOS survey, 78% of Chinese respondents (the highest proportion of surveyed countries) agreed with the statement that products and services using AI have more benefits than drawbacks. After Chinese respondents, those from Saudi Arabia (76%) and India (71%) felt the most positive about AI products. Only 35% of sampled Americans (among the lowest of surveyed countries) agreed that products and services using AI had more benefits than drawbacks.

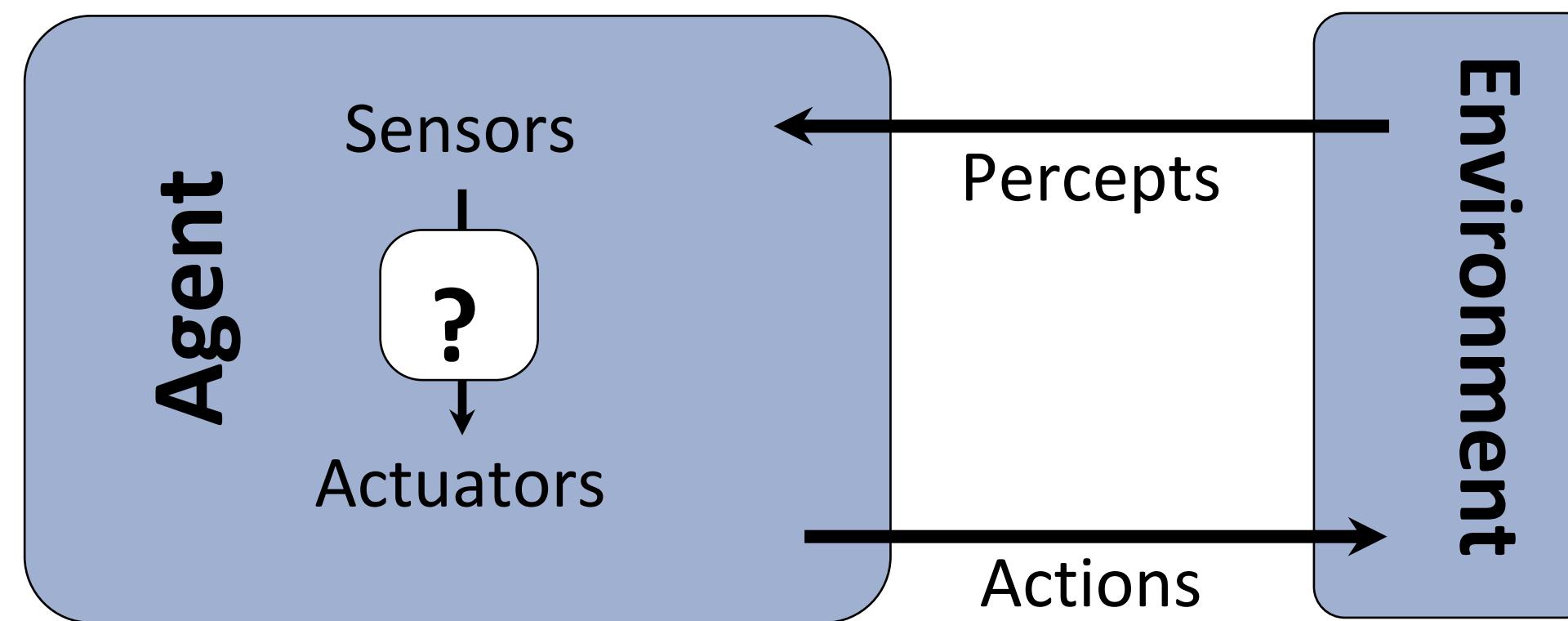
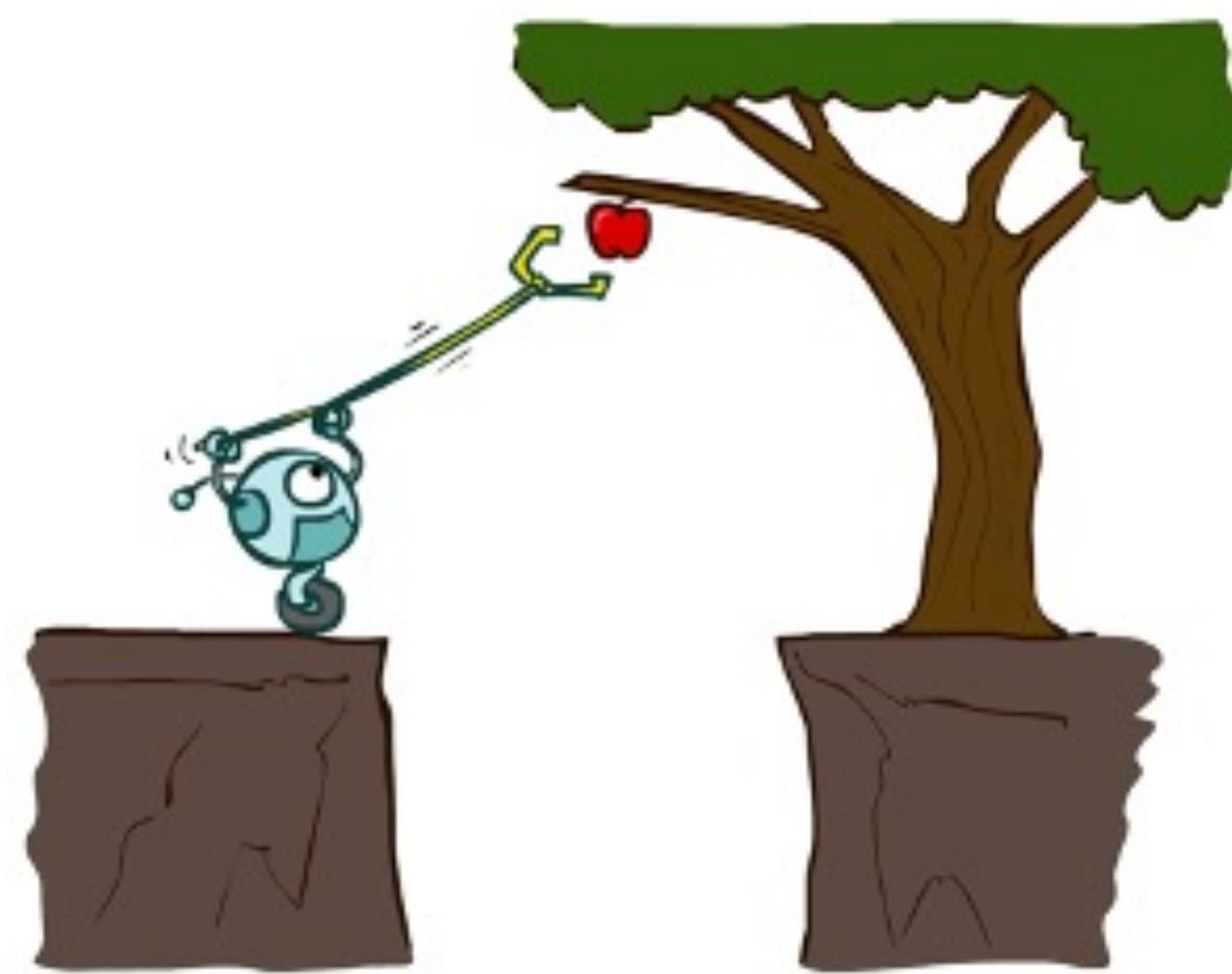
# AI as designing rational agents

- An **agent** is an entity that *perceives* and *acts*.
- A **rational agent** selects actions that maximize its expected utility.
- Characteristics of the **sensors, actuators, and environment** dictate techniques for selecting rational actions
- **This course** is about:
  - General AI techniques for many problem types
  - Learning to choose and apply the technique appropriate for each problem



For details see Chapter 2

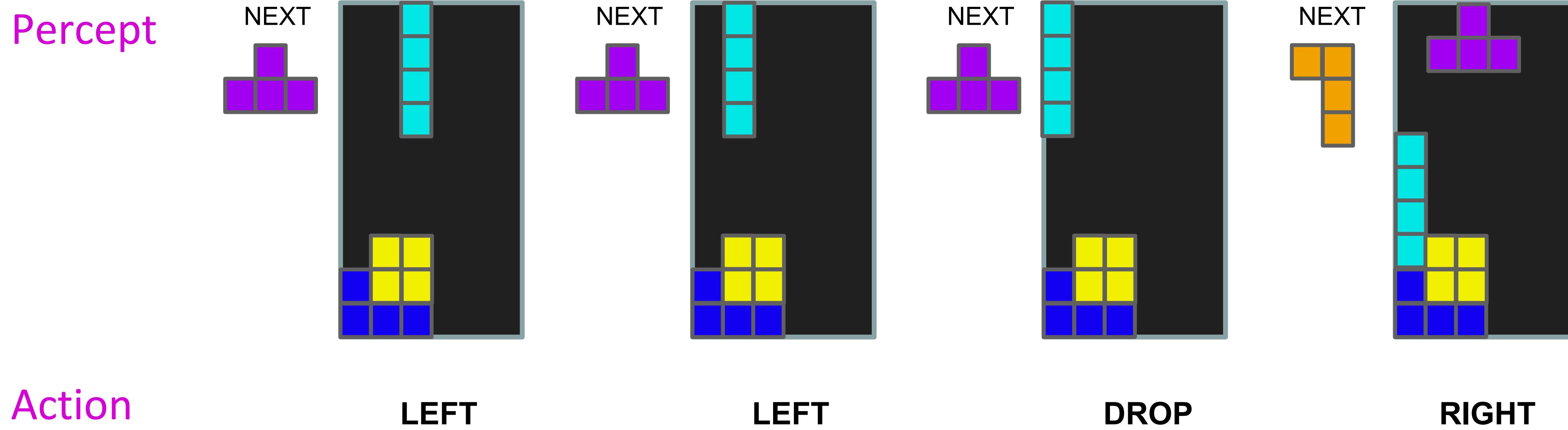
# Agents and environments



- An agent ***perceives*** its environment through ***sensors*** and ***acts*** upon it through ***actuators*** (or *effectors*, depending on whom you ask)

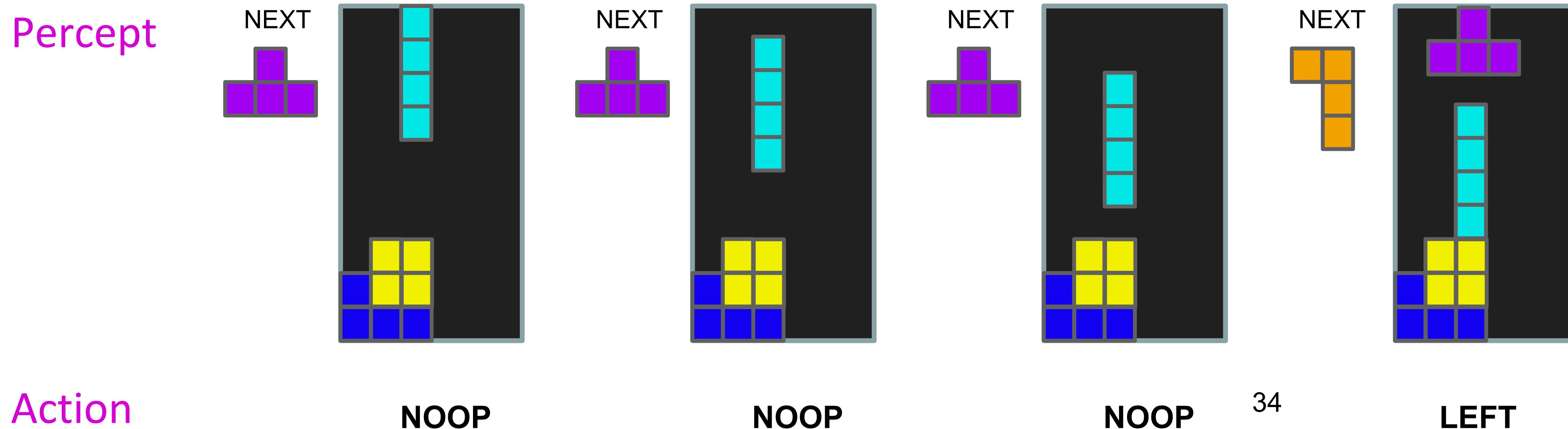
# Agent functions

- The *agent function* maps from percept histories to actions:
  - $f: \mathcal{P}^* \rightarrow \mathcal{A}$
  - I.e., the agent's actual response to any sequence of percepts

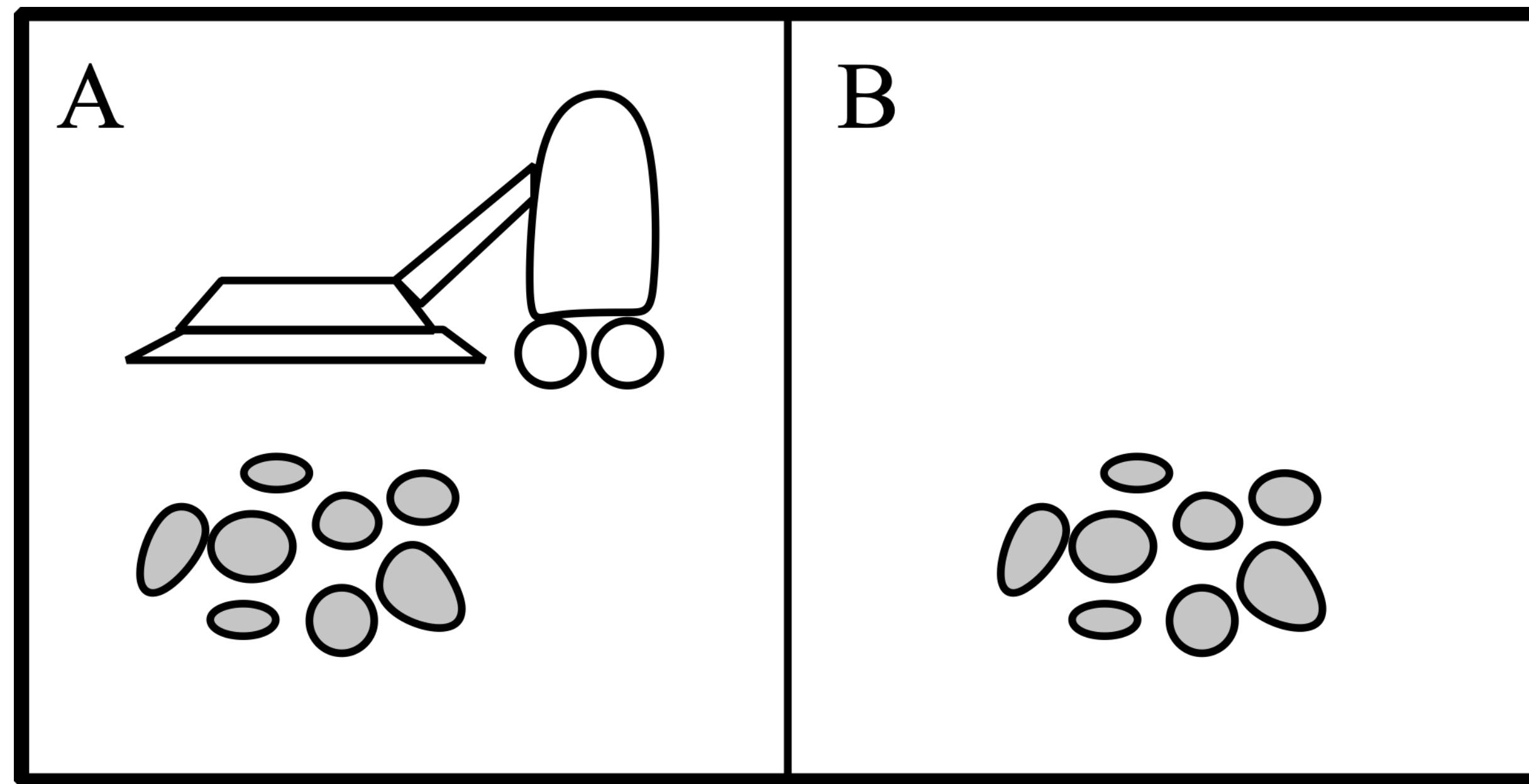


# Agent programs

- The *agent program*  $l$  runs on some machine  $M$  to implement  $f$ :
  - $f = \text{Agent}(l, M)$
  - Real machines have limited speed and memory, introducing delay, so agent function  $f$  depends on  $M$  as well as  $l$

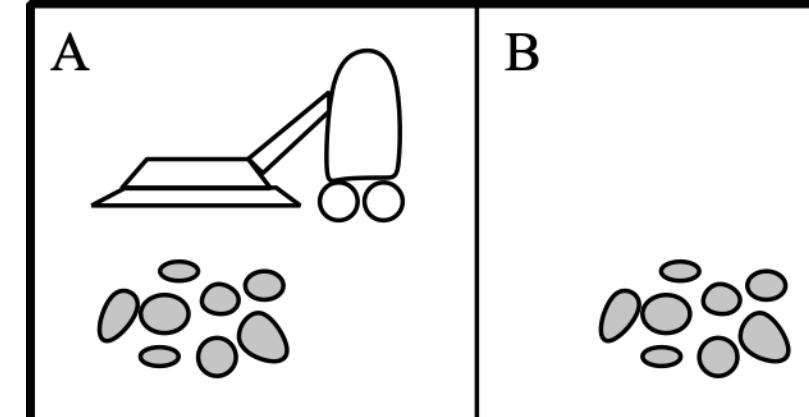


# Example: Vacuum world



- Percepts: [location,status], e.g., [A,Dirty]
- Actions: *Left, Right, Suck, NoOp*

# Vacuum cleaner agent



## *Agent function*

Percept sequence	Action
[A,Clean]	Right
[A,Dirty]	Suck
[B,Clean]	Left
[B,Dirty]	Suck
[A,Clean],[B,Clean]	Left
[A,Clean],[B,Dirty]	Suck
etc	etc

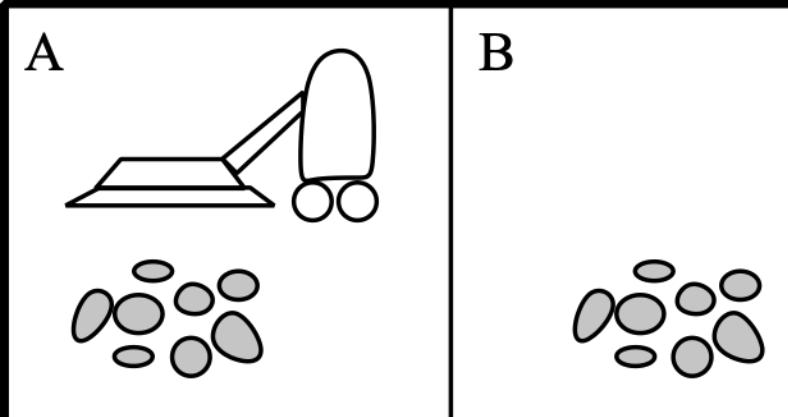
## *Agent program*

```
function Reflex-Vacuum-Agent([location,status])
    returns an action
    if status = Dirty then return Suck
    else if location = A then return Right
    else if location = B then return Left
```

What is the **right** agent function?

Can it be implemented by a small agent program?

# Rationality



- Fixed ***performance measure*** evaluates the environment sequence
  - one point per square cleaned up?
    - NO! Rewards an agent who dumps dirt and cleans it up
  - one point per clean square per time step, for  $t = 1, \dots, T$
- A ***rational agent*** chooses whichever action maximizes the ***expected*** value of the performance measure
  - given the percept sequence to date and prior knowledge of environment
  - Definition, see section 2.2.2 in book

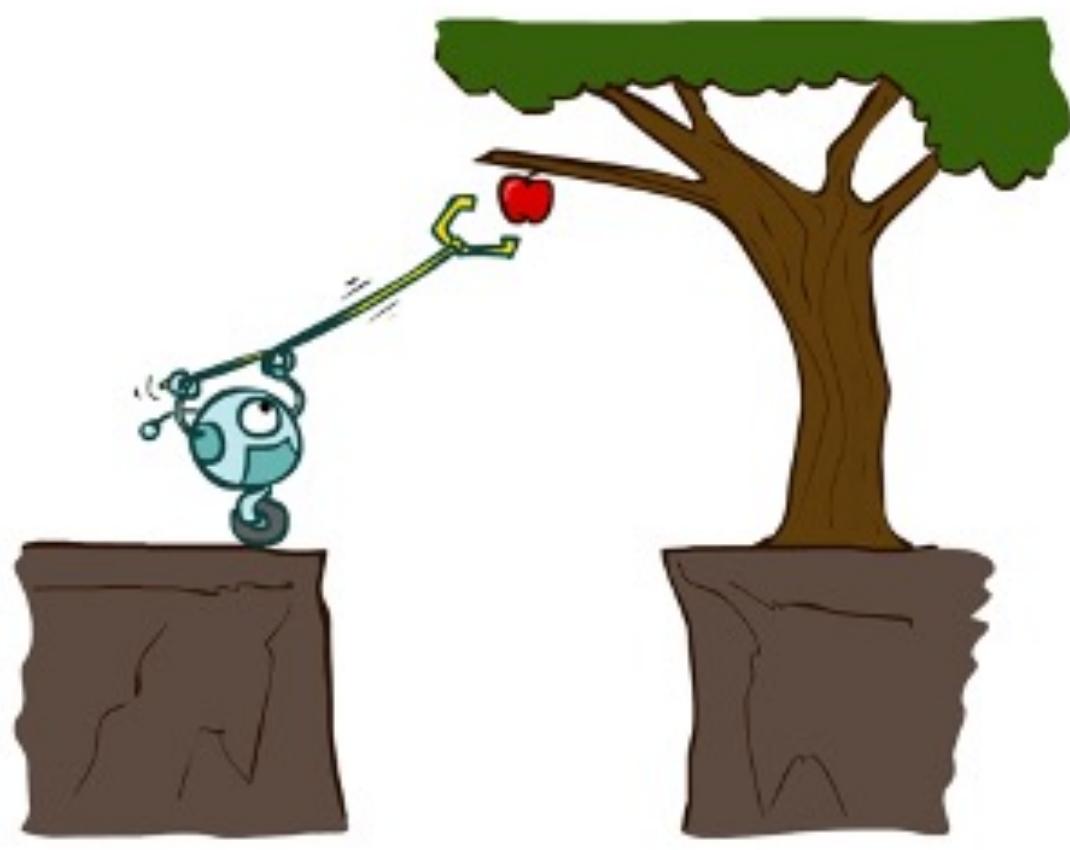
Does Reflex-Vacuum-Agent implement a rational agent function?

Yes, if movement is free, or new dirt arrives frequently

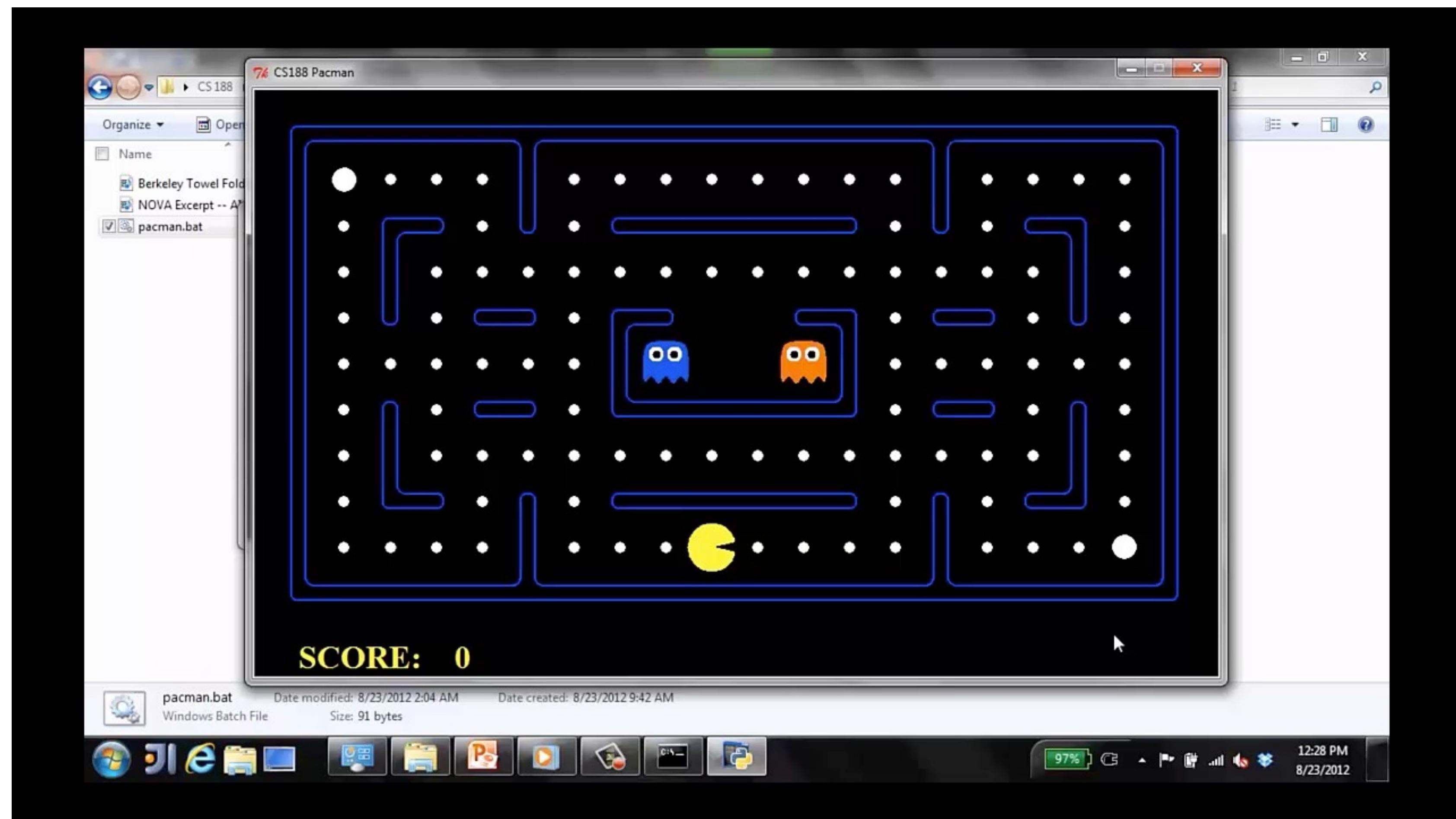
# Rationality, contd.

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- Are rational agents ***omniscient***?
  - No – they are limited by the available percepts
- Are rational agents ***clairvoyant***?
  - No – they may lack knowledge of the environment dynamics
- Do rational agents ***explore*** and ***learn***?
  - Yes – in unknown environments these are essential
- Do rational agents ***make mistakes***?
  - No – but their actions may be unsuccessful
- Are rational agents ***autonomous*** (i.e., transcend initial program)?
  - Yes – as they learn, their behavior depends more on their own experience



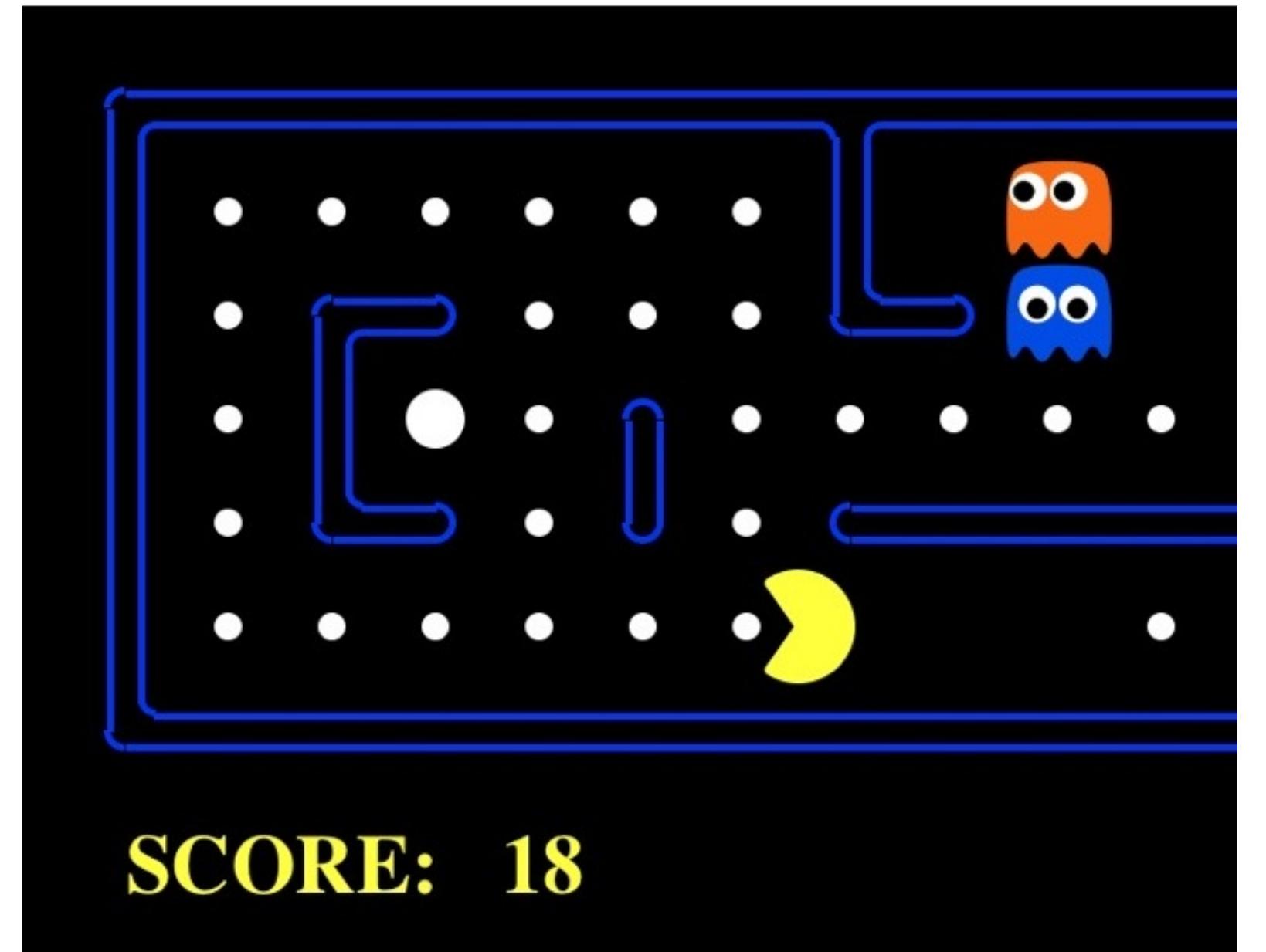
# Pac-man as an agent



Pac-Man is a registered trademark of Namco-Bandai Games, used here for educational purposes

# Task environment - PEAS

- Performance measure
  - -1 per step; + 10 food; +500 win; -500 die; +200 hit scared ghost
- Environment
  - Pacman dynamics (incl ghost behavior)
- Actuators
  - Left Right Up Down or NSEW
- Sensors
  - Entire state is visible (except power pellet duration)



# PEAS for automated Taxi

- Performance measure
  - Income, happy customer, vehicle costs, fines, insurance premiums
- Environment
  - US streets, other drivers, customers, weather, police...
- Actuators
  - Steering, brake, gas, display/speaker
- Sensors
  - Camera, radar, accelerometer, engine sensors, microphone, GPS



Image: <http://nypost.com/2014/06/21/how-google-might-put-taxi-drivers-out-of-business/>

# Environment types

	Pacman	Taxi
Fully or partially observable	F (+/-)	P
Single-agent or multiagent	M	M
Deterministic or stochastic	D	S
Static or dynamic	D	D
Discrete or continuous	C	C
Known physics?	Y	N
Known perf. measure?	Y	N

The environment type largely determines the agent design

**Partially observable** => agent requires **memory** (internal state)

**Stochastic** => agent may have to prepare for **contingencies**

**Multi-agent** => agent may need to behave **randomly**

**Static** => agent has time to compute a rational decision

**Continuous time** => continuously operating **controller**

**Unknown physics** => need for **exploration**

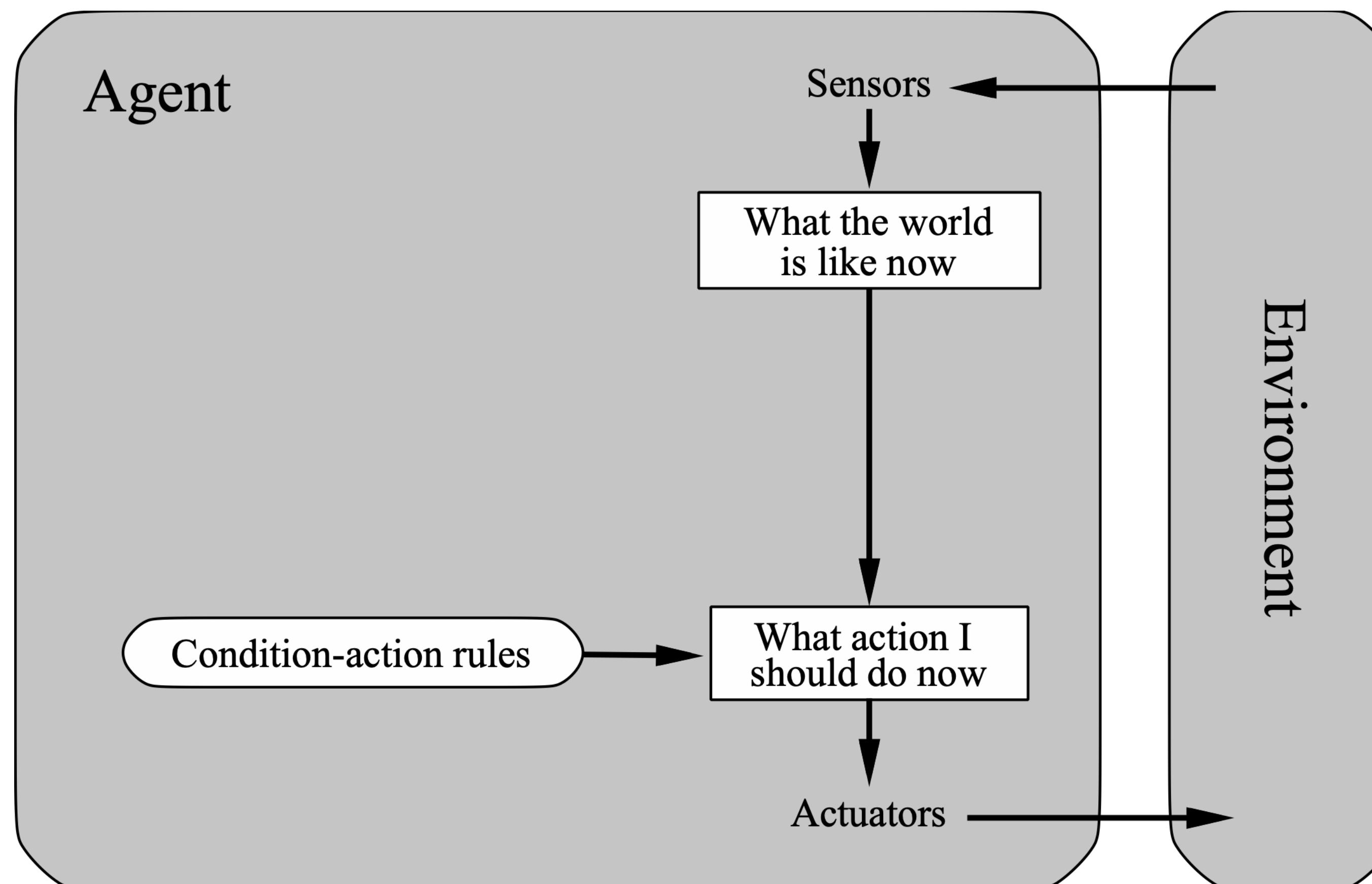
**Unknown perf. measure** => observe/interact with **human principal**

# Agent types

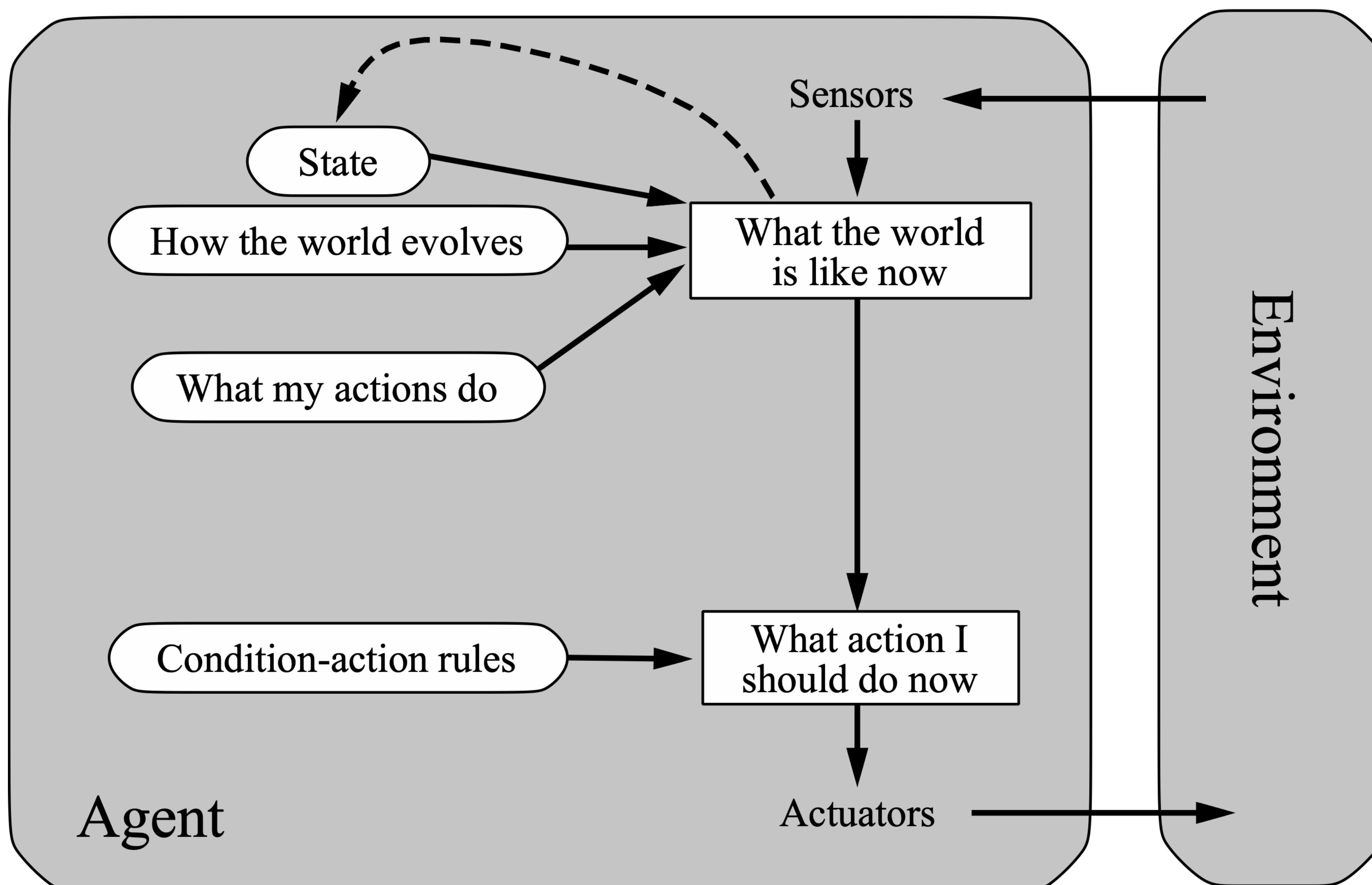
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- In order of increasing generality and complexity
  - Simple reflex agents
  - Reflex agents with state
  - Goal-based agents
  - Utility-based agents

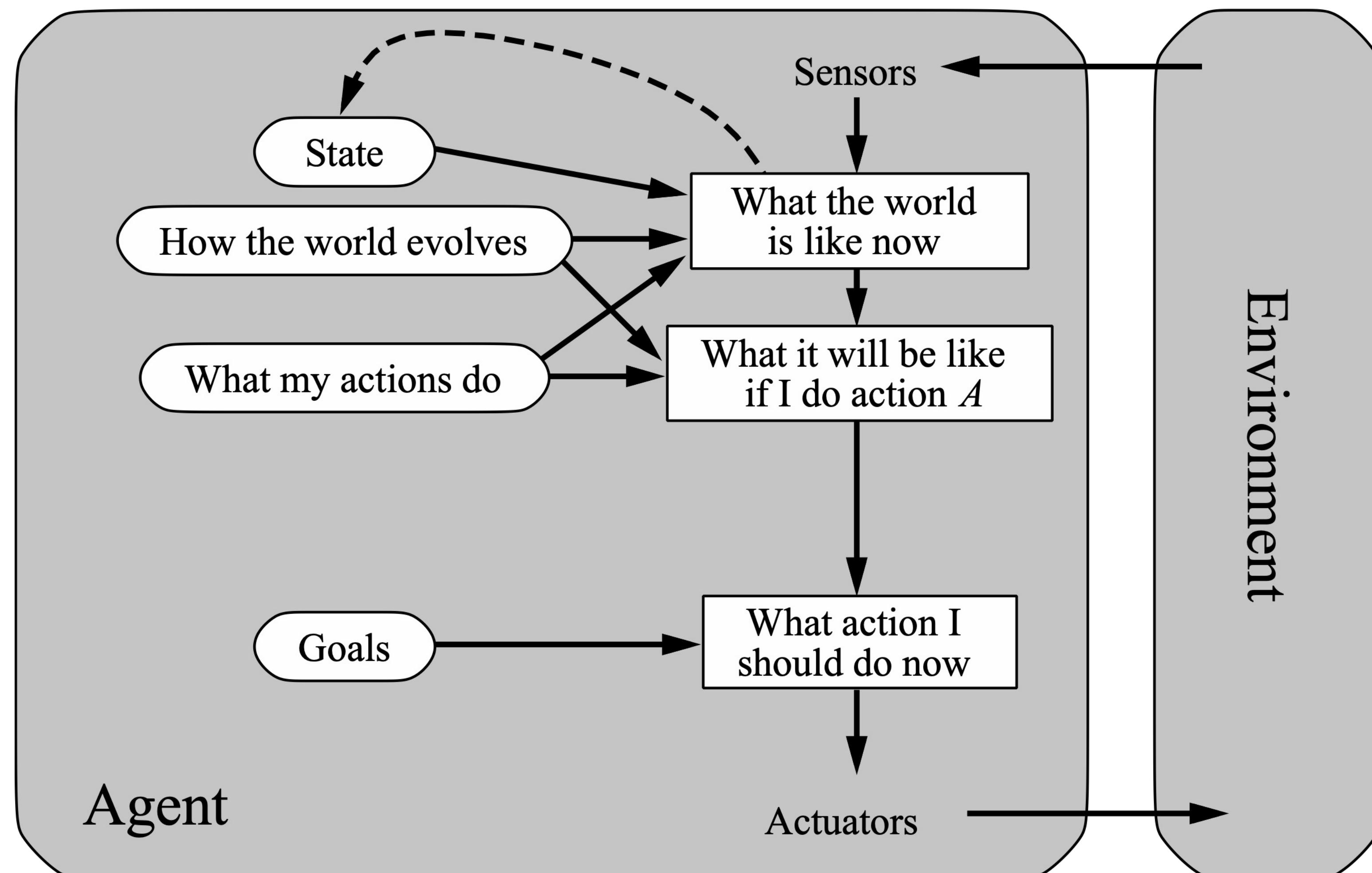
# The simple reflex agent



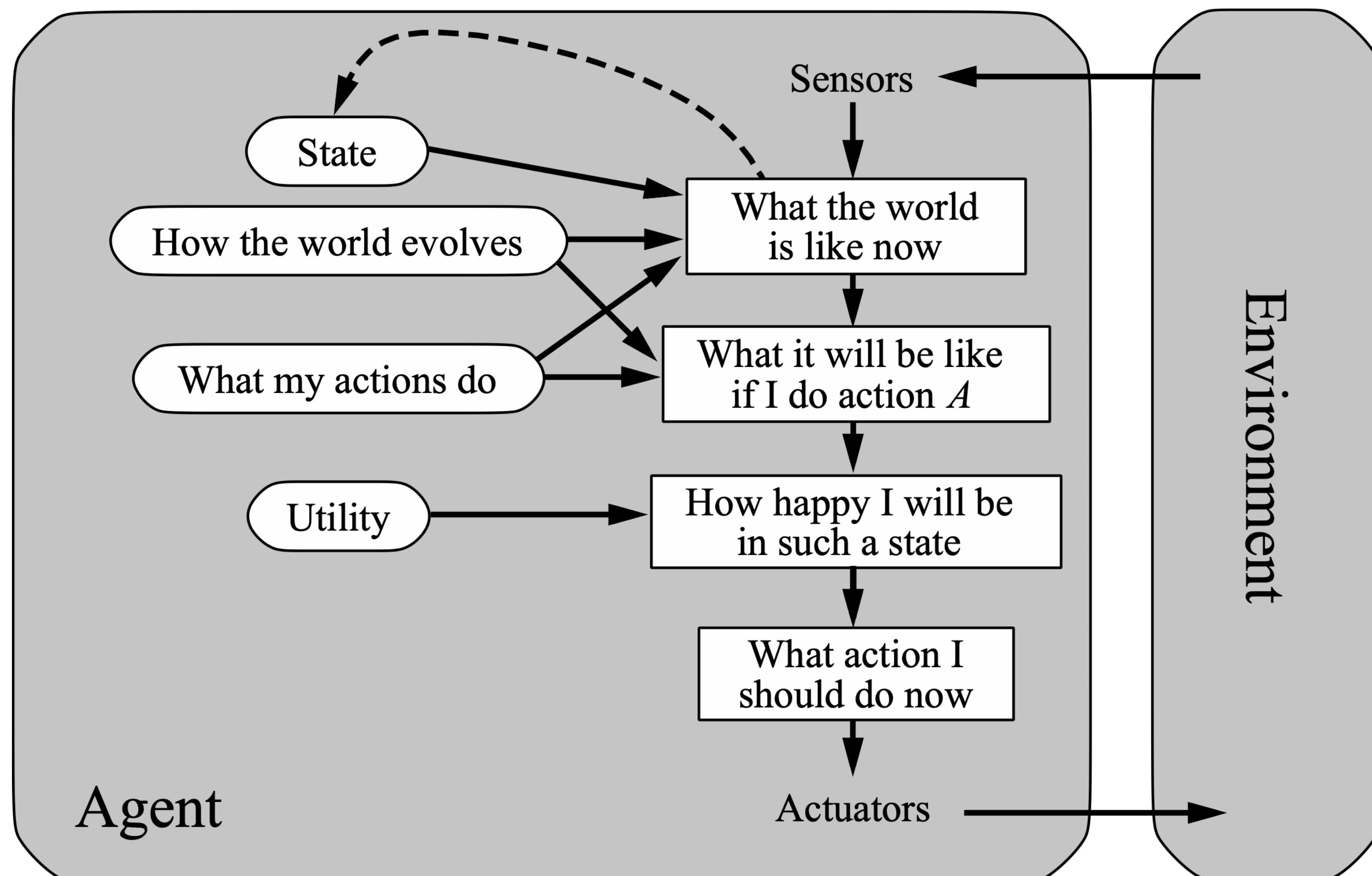
# Reflex agent with state



# Goal-based agent



# Utility-based agent



- An **agent** interacts with an **environment** through **sensors** and **actuators**
- The **agent function**, implemented by an **agent program** running on a **machine**, describes what the agent does in all circumstances
- Rational agents choose actions that maximize their expected utility
- PEAS descriptions define task environments; precise PEAS specifications are essential and strongly influence agent designs
- More difficult environments require more complex agent designs and more sophisticated representations