All of Artificial Intelligence

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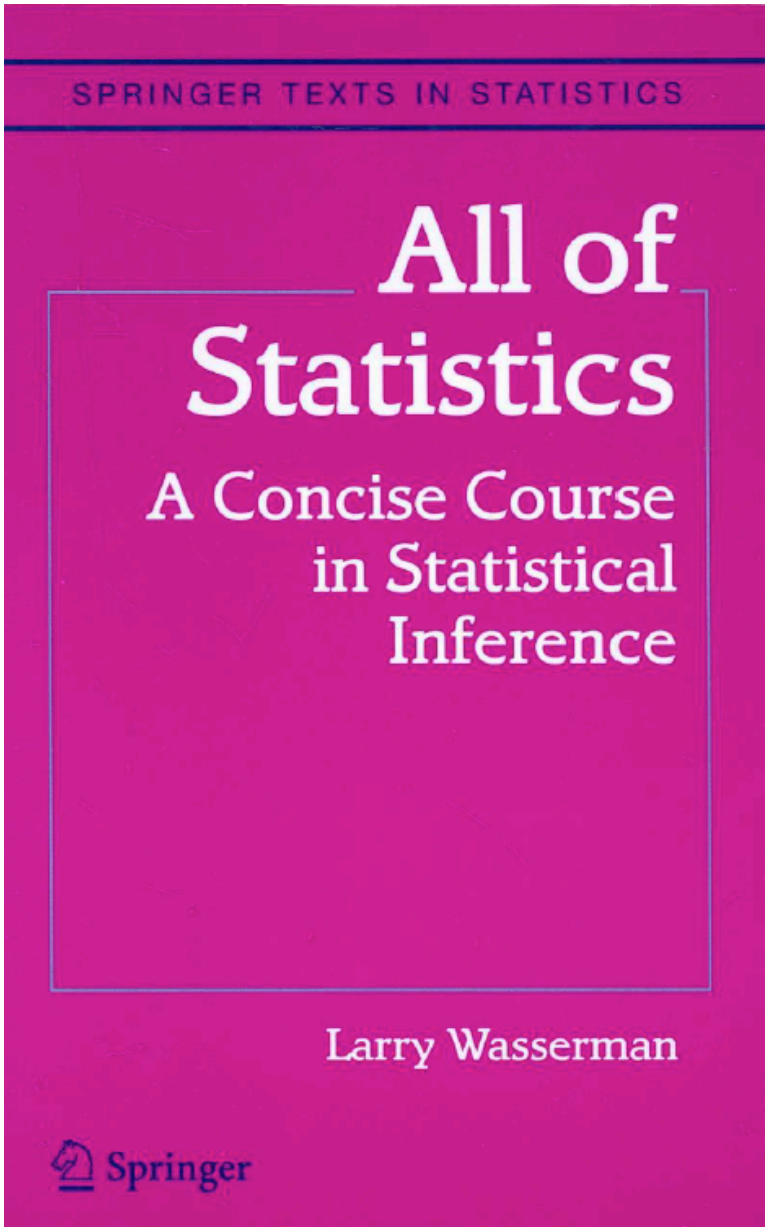
COMPHI Lab of Data Science

December 2018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A Concise Course in Statistical Inference
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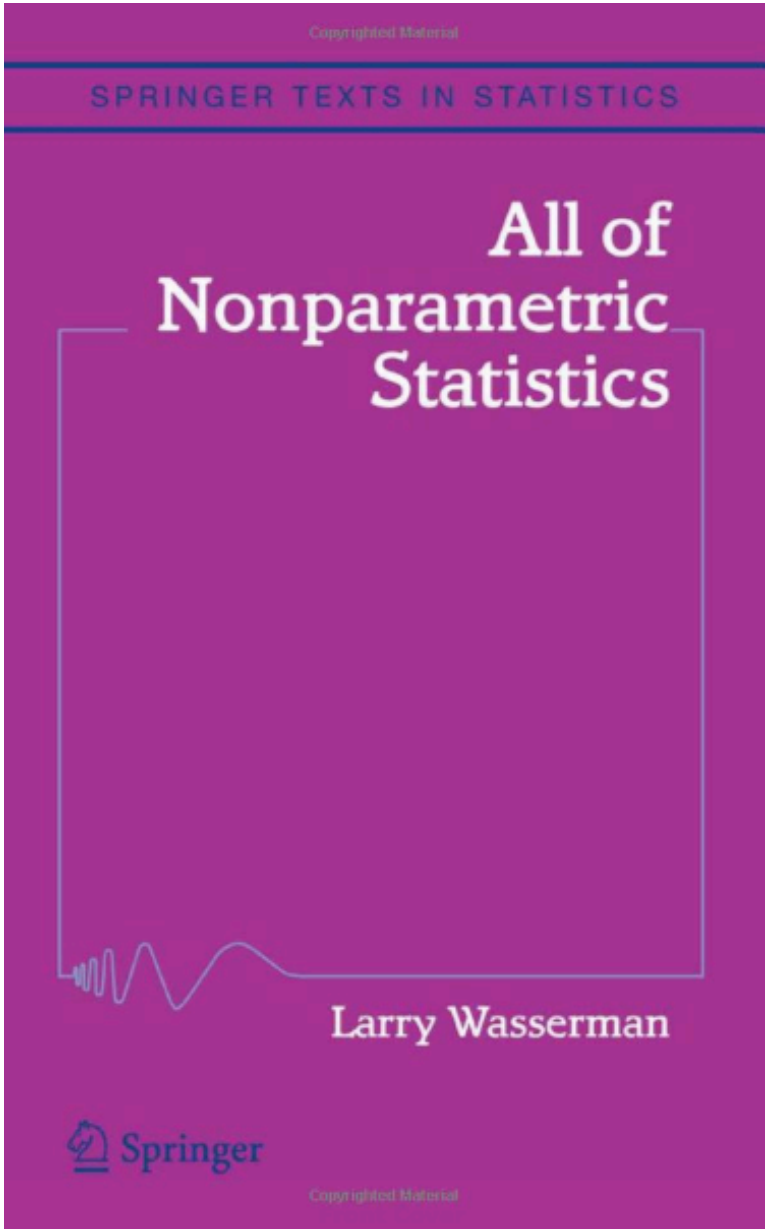
Springer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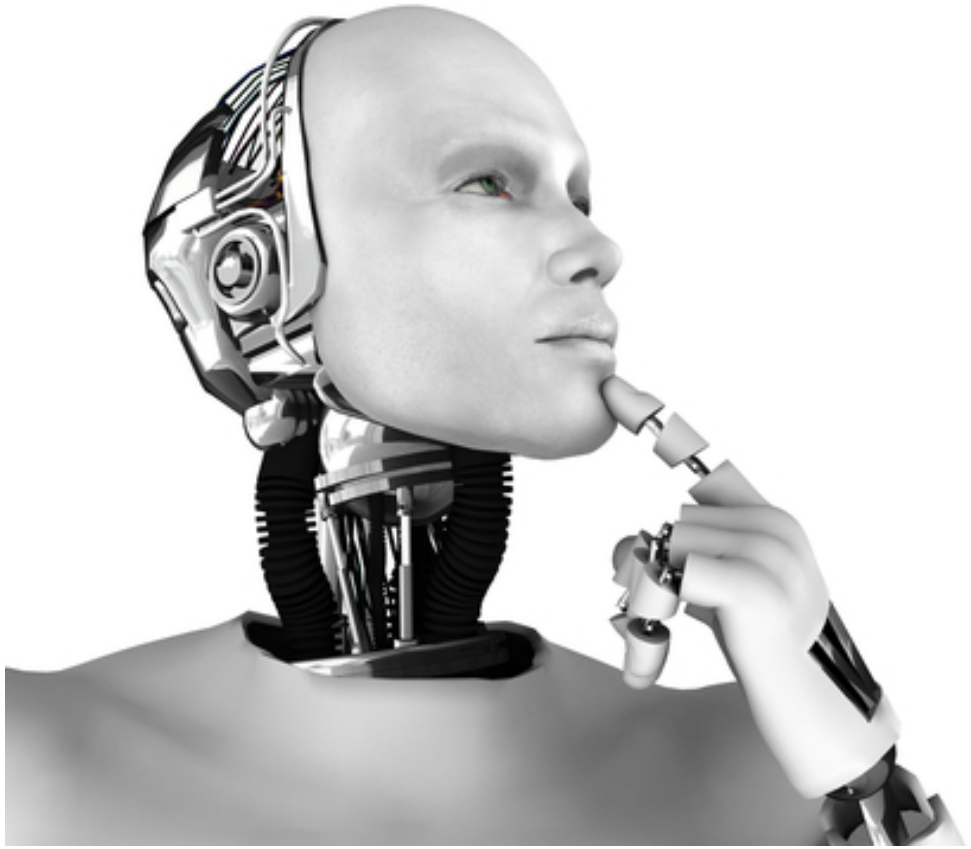
Outline

1. Milestones in the History of AI
2. Areas and Applications of AI
3. AI Technology: Deeper Down the Rabbit Hole
4. AI and Philosophy

The Purpose of AI

- The goal of Artificial Intelligence is to build artifacts or machines that ... ?



Build Computers that ...

Think like humans	Think rationally
Act like humans	Act rationally

- Requires (presumably) that we have some knowledge of how humans think; currently more the purview of cognitive science
- "May not machines carry out something which ought to be described as thinking but which is very different from what a man does?" - Alan Turing

Build Computers that ...

Think like humans	Think rationally
Act like humans	Act rationally

- The fields of logic and automated reasoning, a common theme in much original AI research
- Searching through logical deductions proved a very computationally intensive task, and it is unclear whether logic is a good basis for the "more vague" notions of knowledge.

Build Computers that ...

Think like humans	Think rationally
Act like humans	Act rationally

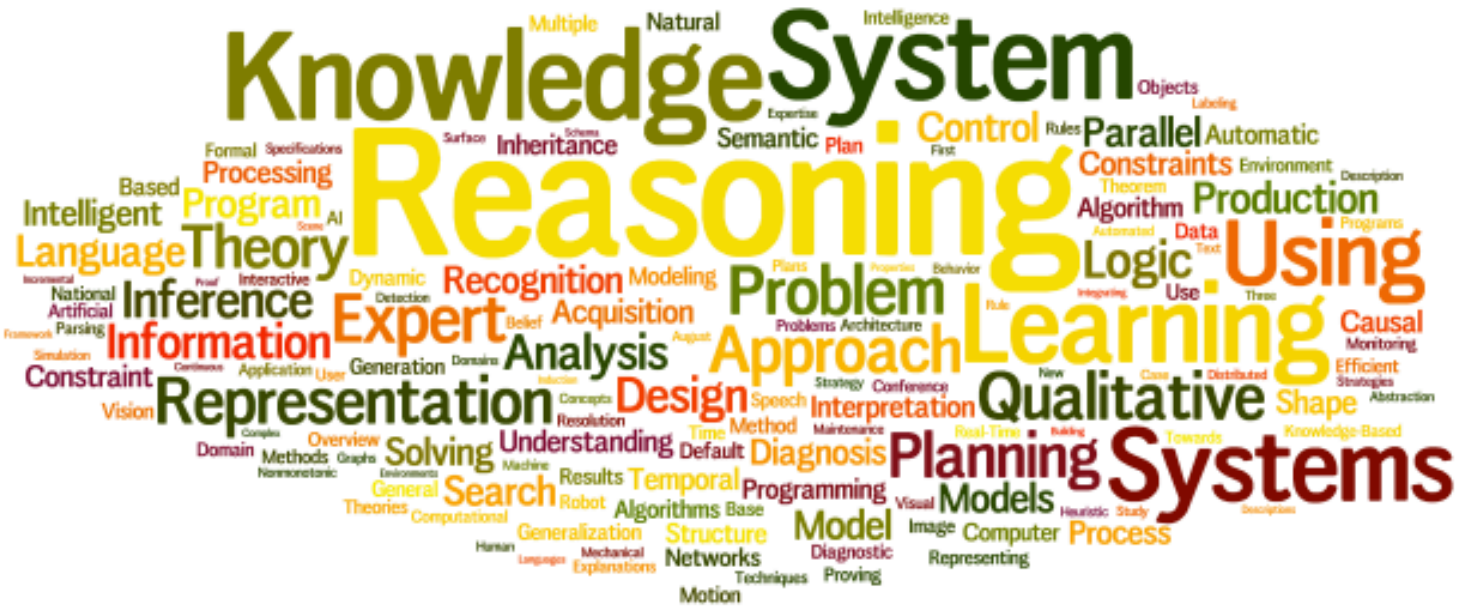
- The Turing Test: talk to a computer or human for an hour, can you tell which one?
- Interviewer: "What is 32,839 × 128,394?"
  Computer: "I don't know!"

Build Computers that ...

Think like humans	Think rationally
Act like humans	Act rationally

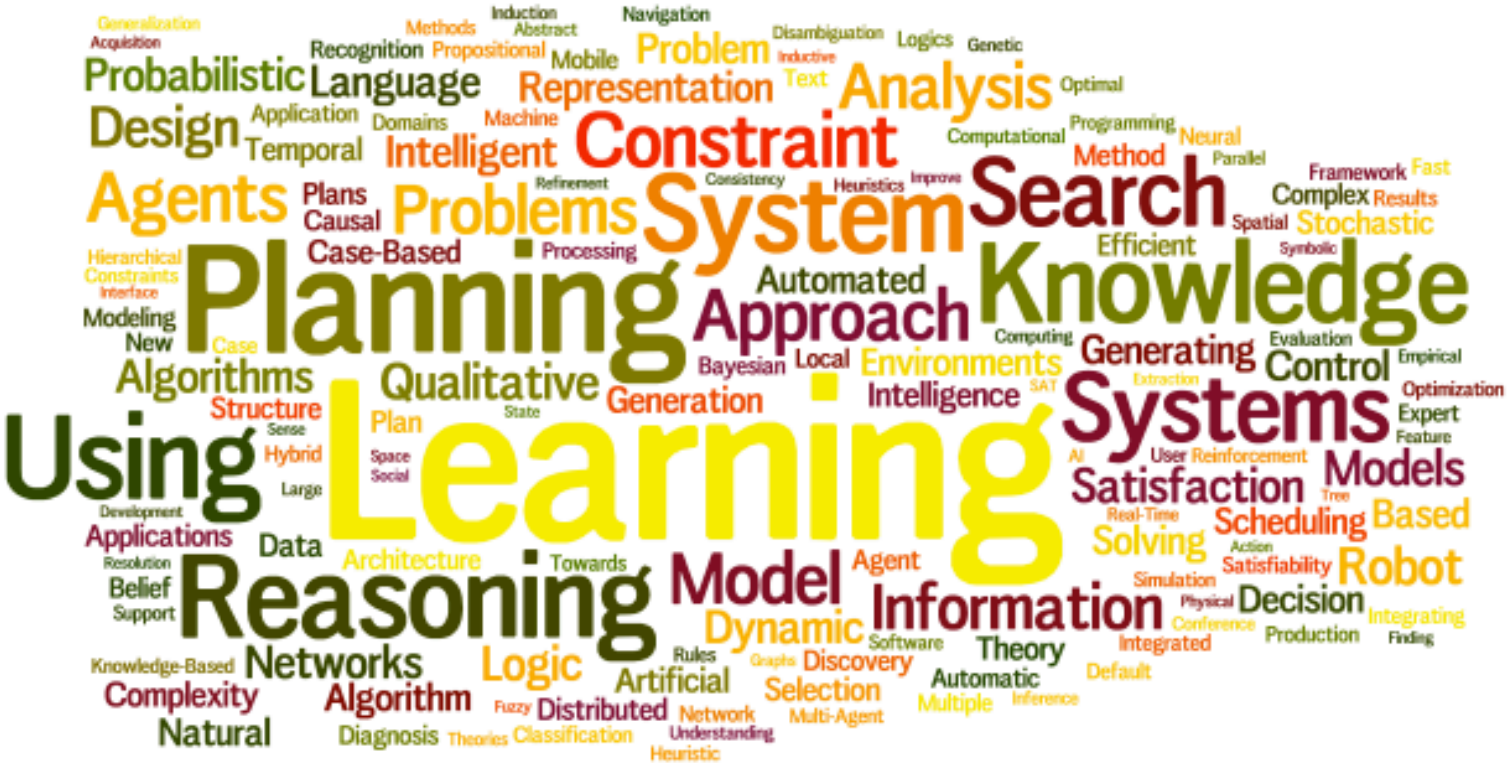
- The basis for the "intelligent agent" framework in Russell and Norvig
- Unclear if this accurately captures the scope of current AI research, or if AI researchers see themselves as working toward this goal.

The Pragmatist's View



1980s

The Pragmatist's View



1990s

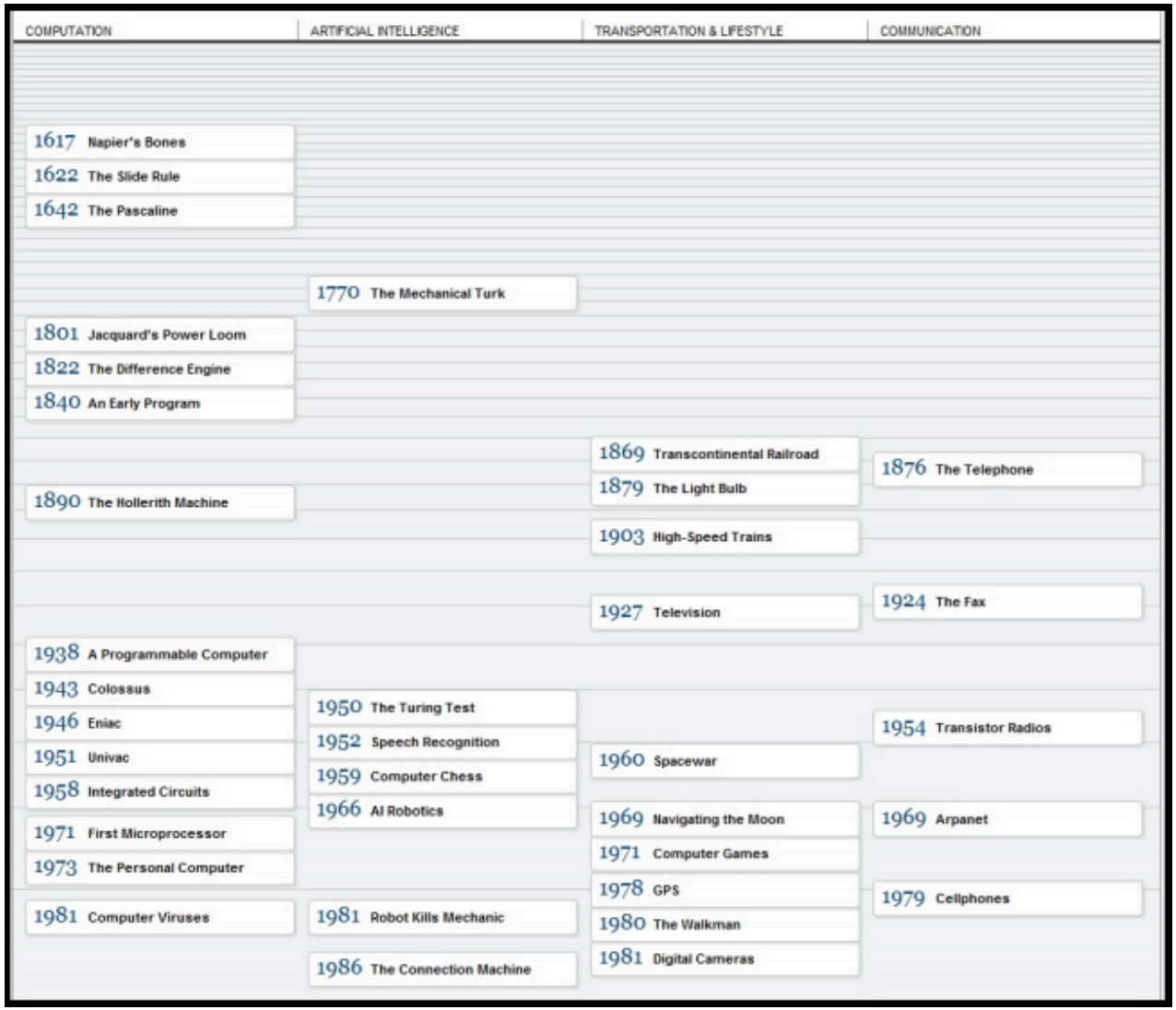
The Pragmatist's View

2000s

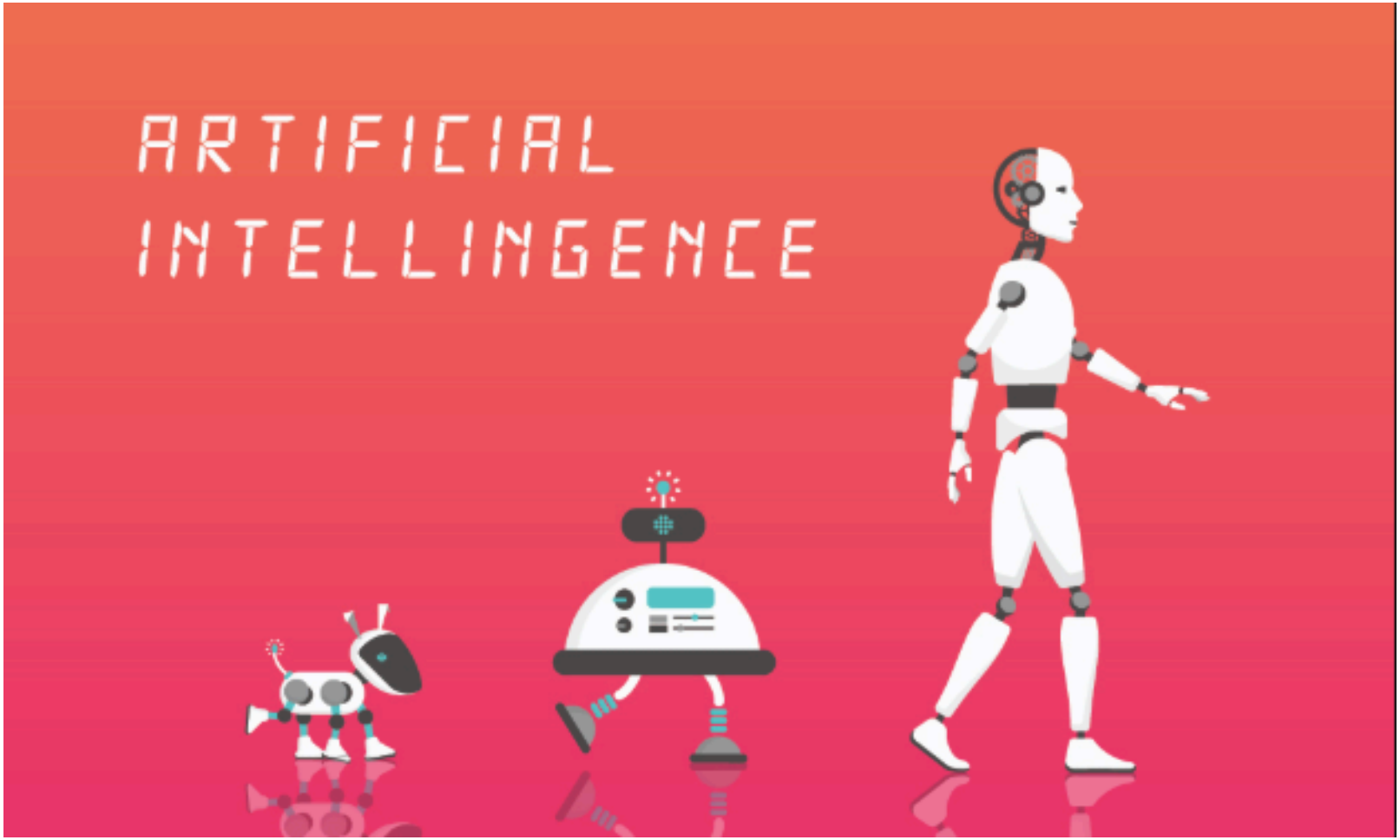
The Pragmatist's View

2010s

AI Timeline


COMPUTATION
ARTIFICIAL INTELLIGENCE
TRANSPORTATION & LIFESTYLE
COMMUNICATION
1617 Napier's Bones
1622 The Slide Rule
1642 The Pascaline
1770 The Mechanical Turk
1801 Jacquard's Power Loom
1822 The Difference Engine
1840 An Early Program
1869 Transcontinental Railroad
1876 The Telephone
1879 The Light Bulb
1890 The Hollerith Machine
1903 High-Speed Trains
1927 Television
1924 The Fax
1938 A Programmable Computer
1943 Colossus
1950 The Turing Test
1946 Eniac
1954 Transistor Radios
1952 Speech Recognition
1951 Univac
1960 Spacewar
1959 Computer Chess
1958 Integrated Circuits
1966 AI Robotics
1969 Navigating the Moon
1969 Arpanet
1971 First Microprocessor
1971 Computer Games
1973 The Personal Computer
1978 GPS
1979 Cellphones
1981 Computer Viruses
1981 Robot Kills Mechanic
1980 The Walkman
1981 Digital Cameras
1986 The Connection Machine

Milestones in AI

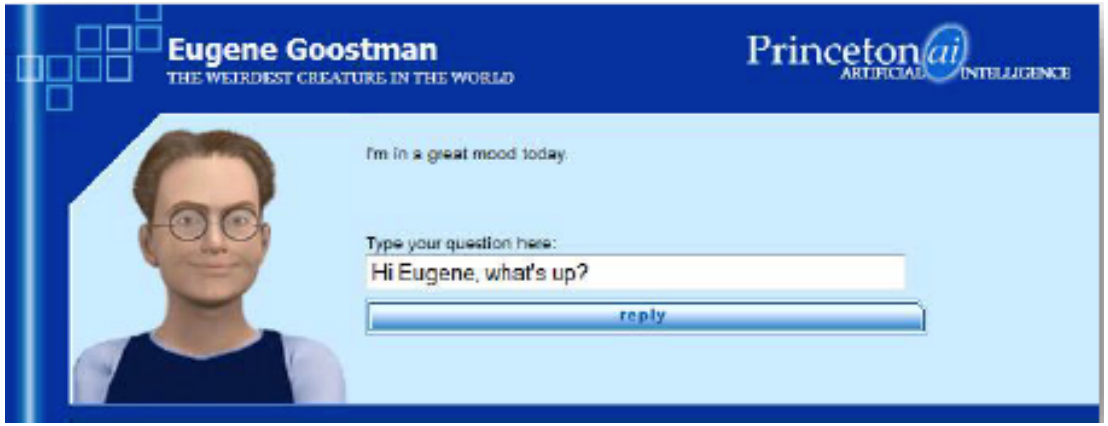


1950

1. 1950 paper, "Computing Machinery and Intelligence," introduces Turing test
2. Interviewer talks to a person and machine via a terminal interface, must determine which is which

Eugene Goostman

1. Turing predicted that a chatbot would convince 30% of judges by 2000.
2. Eugene Goostman achieved this milestone in June 2014.
3. Is it really intelligent?



1952-1959

1. Arthur Samuel develops checkers program while at IBM
2. Program includes a version of alpha-beta pruning in game search, position scoring, and learning from self-play

1952-1959

1. Alan Newell, Herbert Simon, J.C. Shaw develop Logic Theorist, which sought to prove mathematical theorems form Principia Mathematica
2. A pioneering effort in intelligence as search, found a shorter proof of one well-known theorem

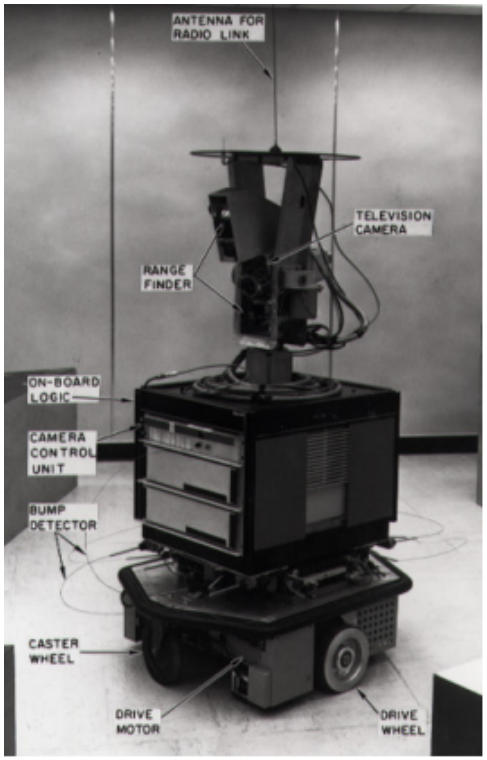
1956

Dartmouth Conference on Artificial Intelligence, organized by John McCarthy, Marvin Minksy, Nathaniel Rochester, and Claude Shannon

1958

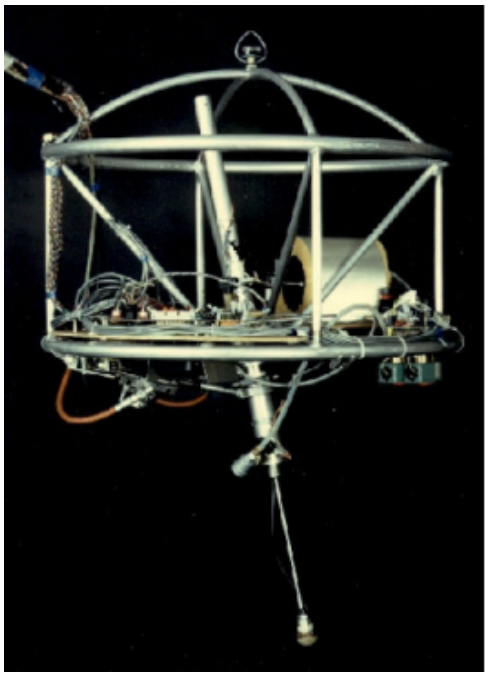
Frank Rosenblatt's Perceptron algorithm learns to recognize letters of the alphabet from images

1966-1972



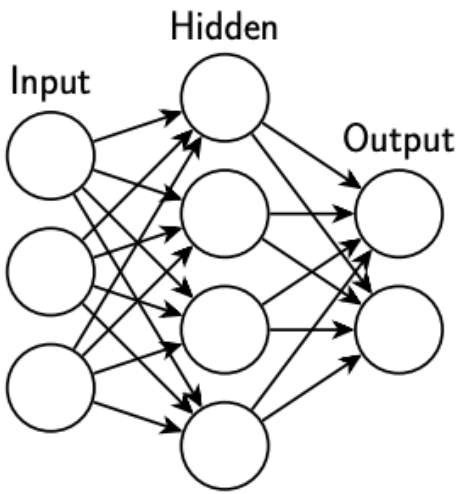
1. Shakey the robot developed at Stanford Research Institute
2. Goal is to develop a general purpose robot capable of reasoning and interacting with the world

1980-1988



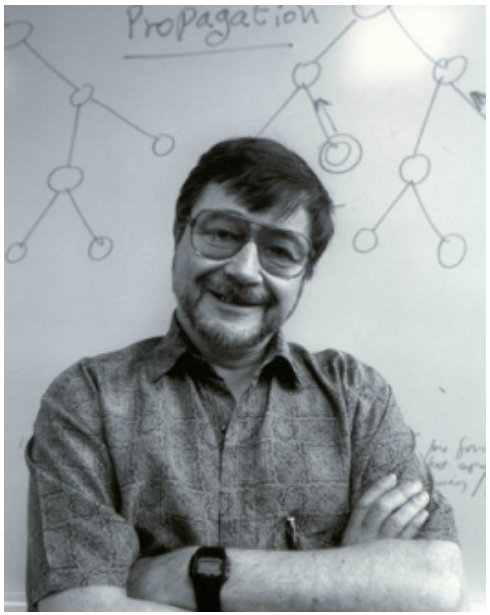
Marc Raibert of CMU and MIT develops hopping robots

1982



Backpropagation for training multi-layer neural networks popularized by David Rumelhart, John Hopfield (amongst many others)

1988



Judea Pearl publishes Probabilistic Reasoning in Intelligent Systems, bring probability and Bayesian networks to forefront of AI

1997

Deep blue defeats Gary Kasparov in a six-game chess match (two wins, one loss, three draws)

2005-2007

Stanford and CMU respectively win 2005 and 2007 DARPA Challenges, requiring a car to drive autonomously through desert and simulated urban environments.

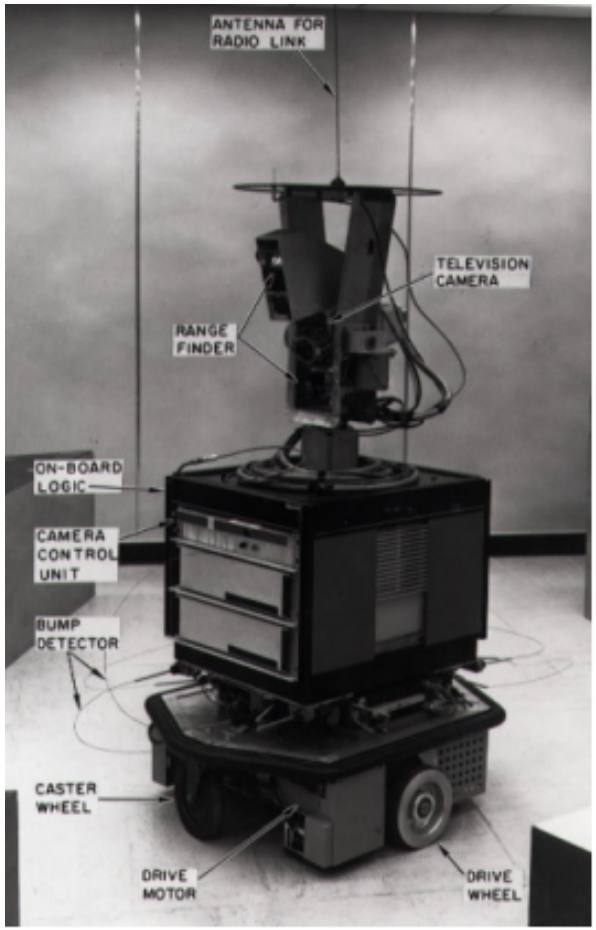
2011

IBM's Watson defeats human opponents on Jeopordy.

2016

1. In March 2016, AlphaGo beat the 9-dan player Lee Sedol 4-1
2. It is based on deep learning and reinforcement learning
3. Closer to general AI than Deep Blue or Watson

Shakey The Robot



What would be like to build a robot assistant?

A “Simple” Task

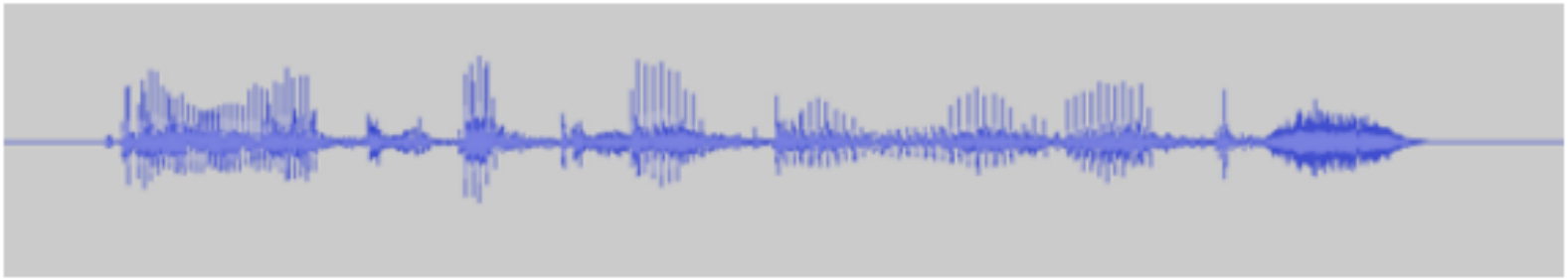
“Bring me a cup of coffee in my office”

A "Simple" Task: Retated Areas of AI Research

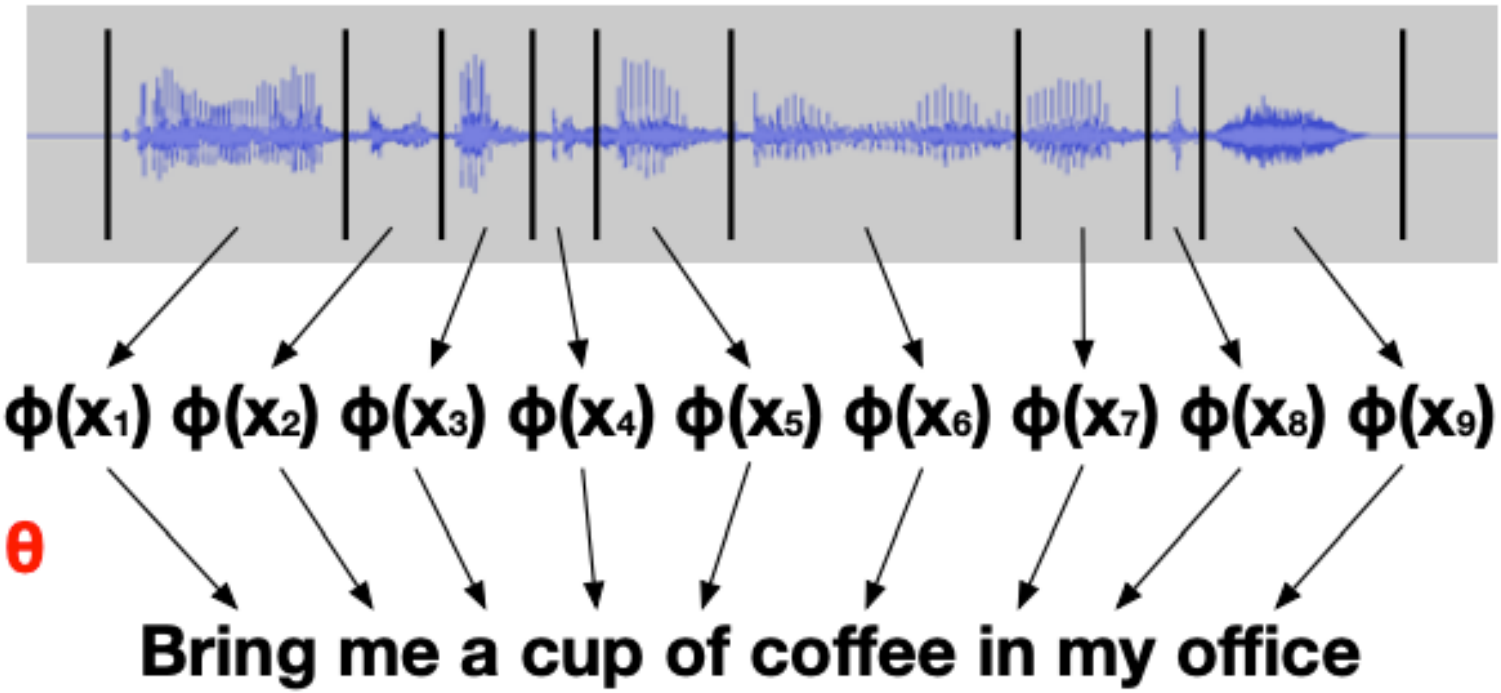
1. Speach Recognition
2. Probablistic Modeling, Bayesian Networks
3. Natural Language Processing
4. Planning
5. Search
6. Computer Vision
7. Robot Manipulation
8. Numerical Optimization
9. Reinforcement Learning
10. Scheduling
11. Computational Game Theory

...

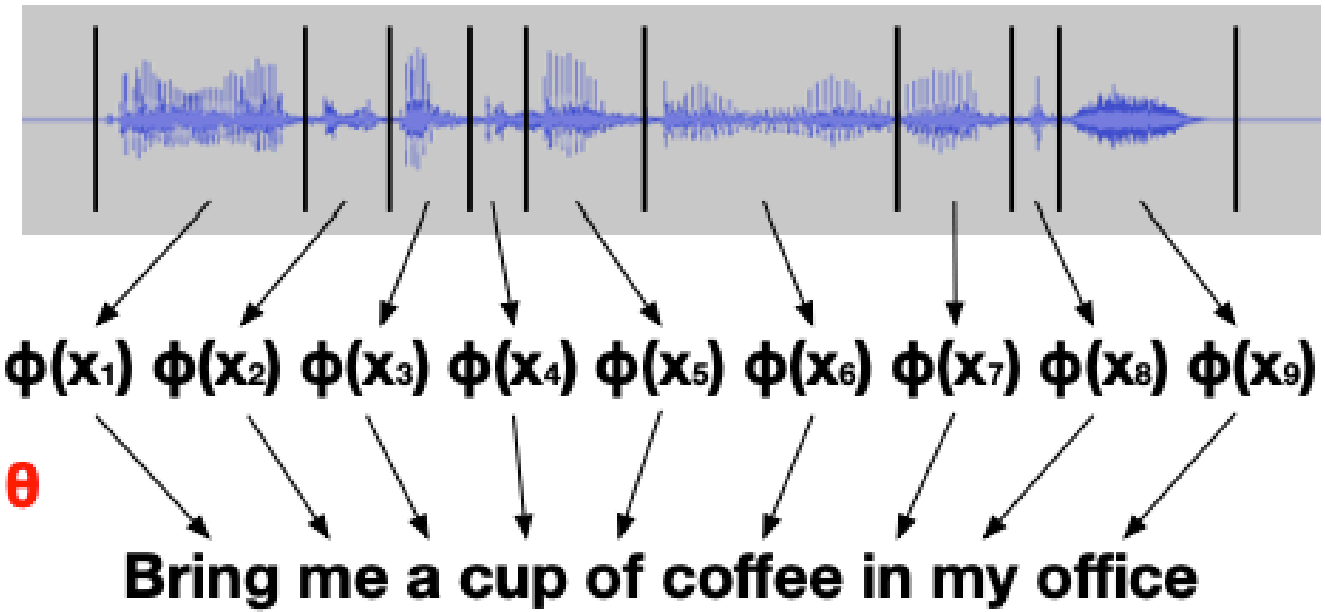
Speech Recognition

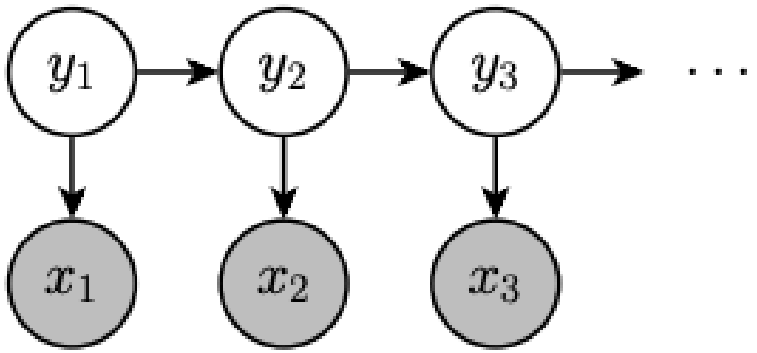


Speech Recognition

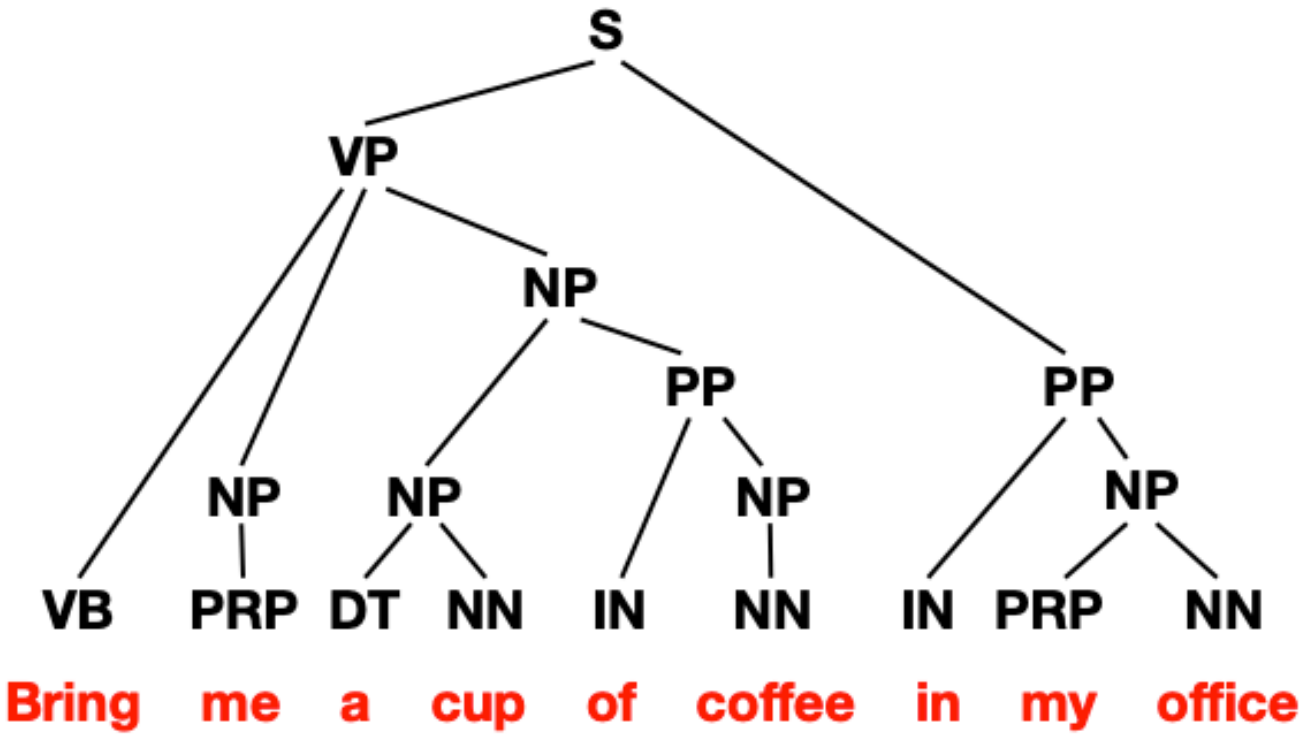


Probablistic Modeling





Natural Language Processing



Planning

ACTION: POUR-COFFEE

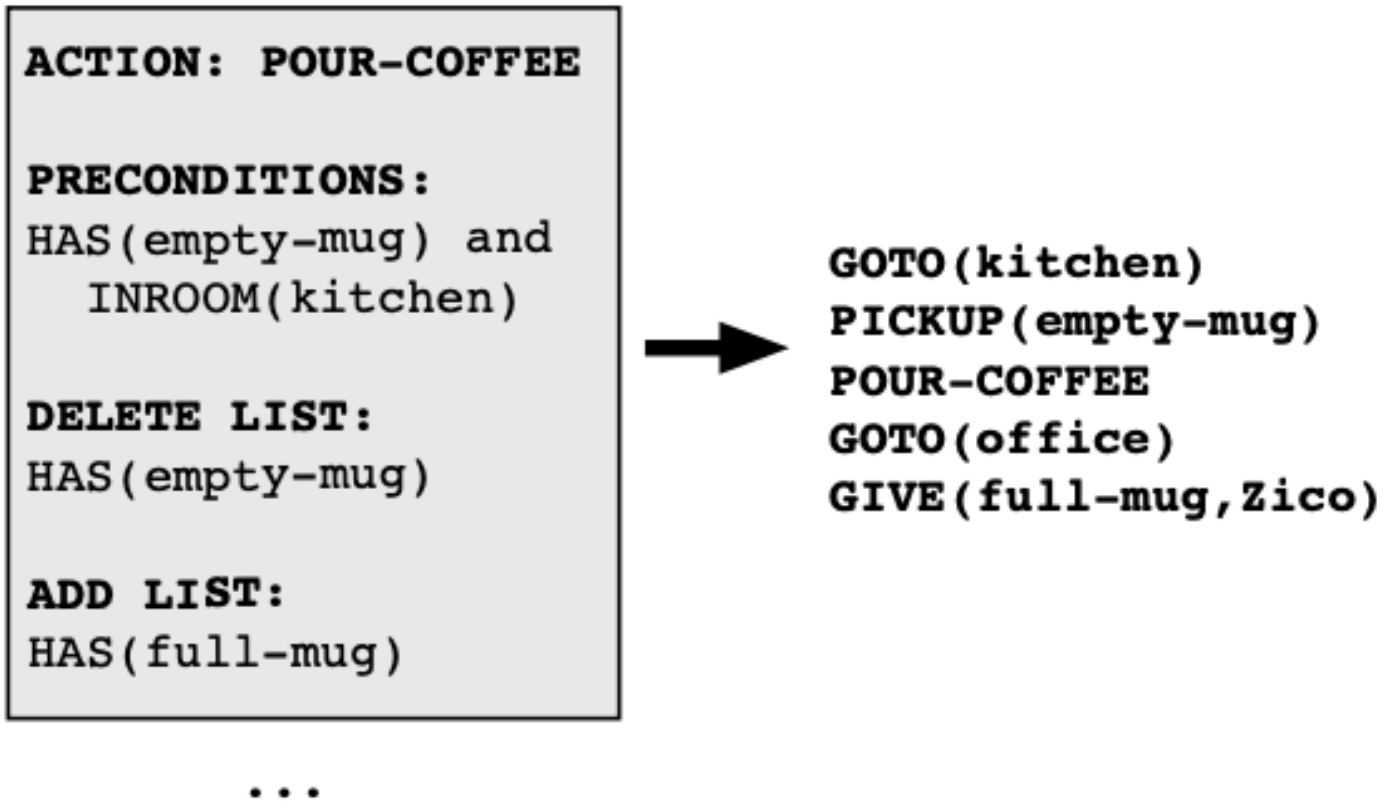
PRECONDITIONS:
HAS(empty-mug) and
INROOM(kitchen)

DELETE LIST:
HAS(empty-mug)

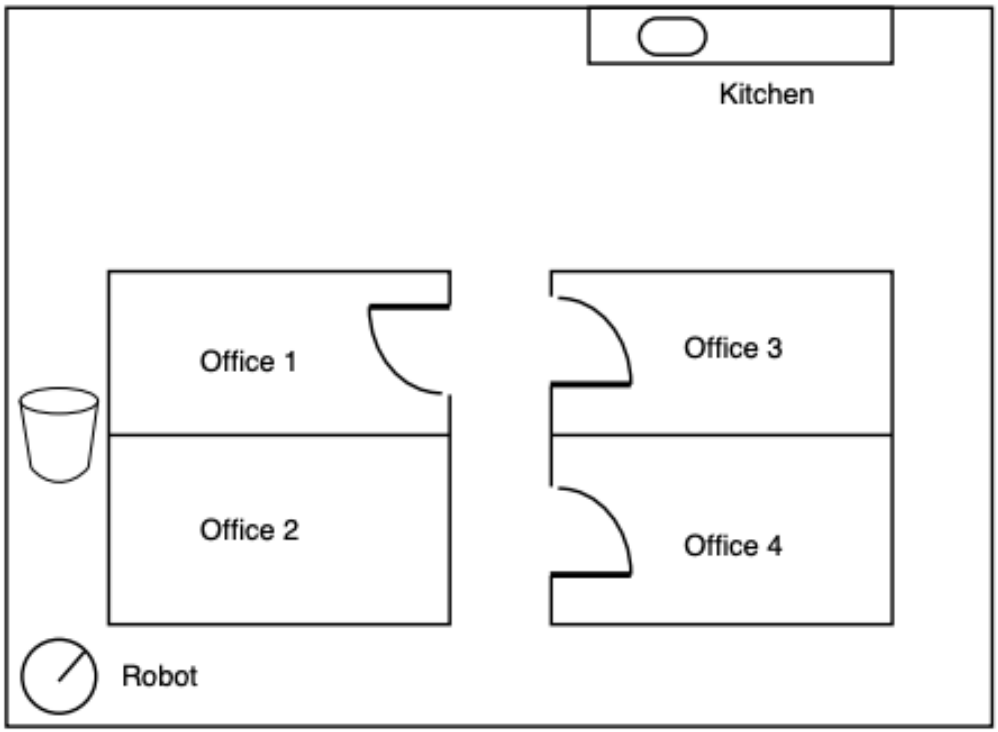
ADD LIST:
HAS(full-mug)

...

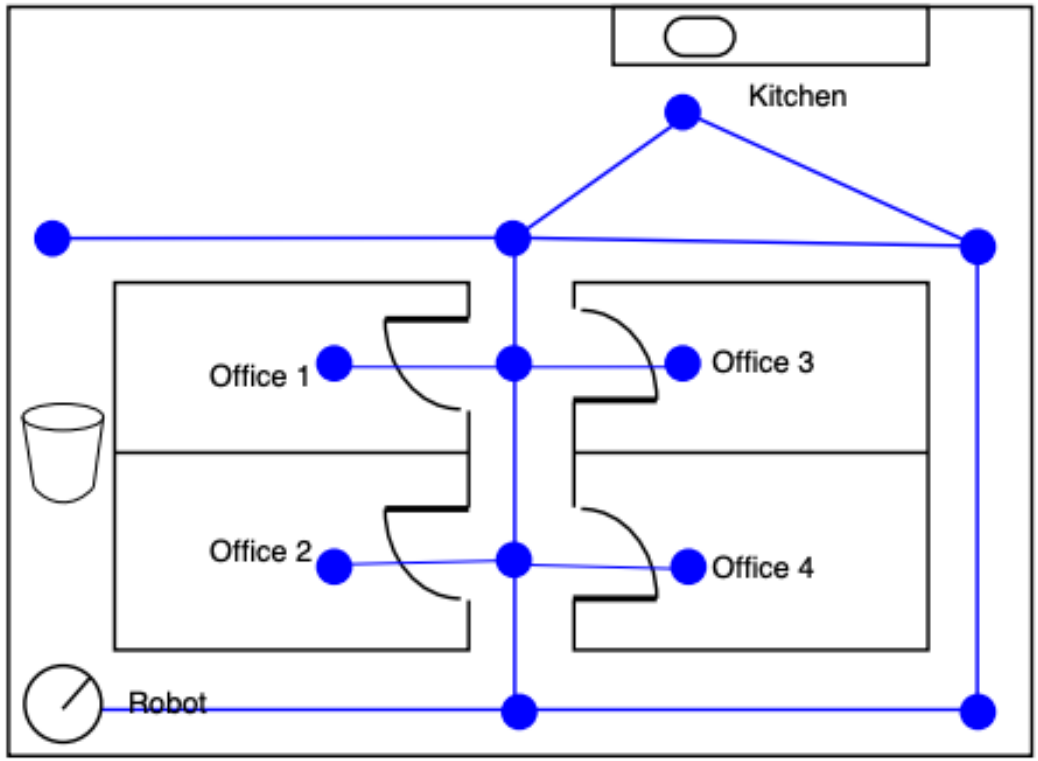
Planning


ACTION: POUR-COFFEE
PRECONDITIONS:
HAS(empty-mug) and
INROOM(kitchen)
DELETE LIST:
HAS(empty-mug)
ADD LIST:
HAS(full-mug)
...
GOTO(kitchen)
PICKUP(empty-mug)
POUR-COFFEE
GOTO(office)
GIVE(full-mug,Zico)

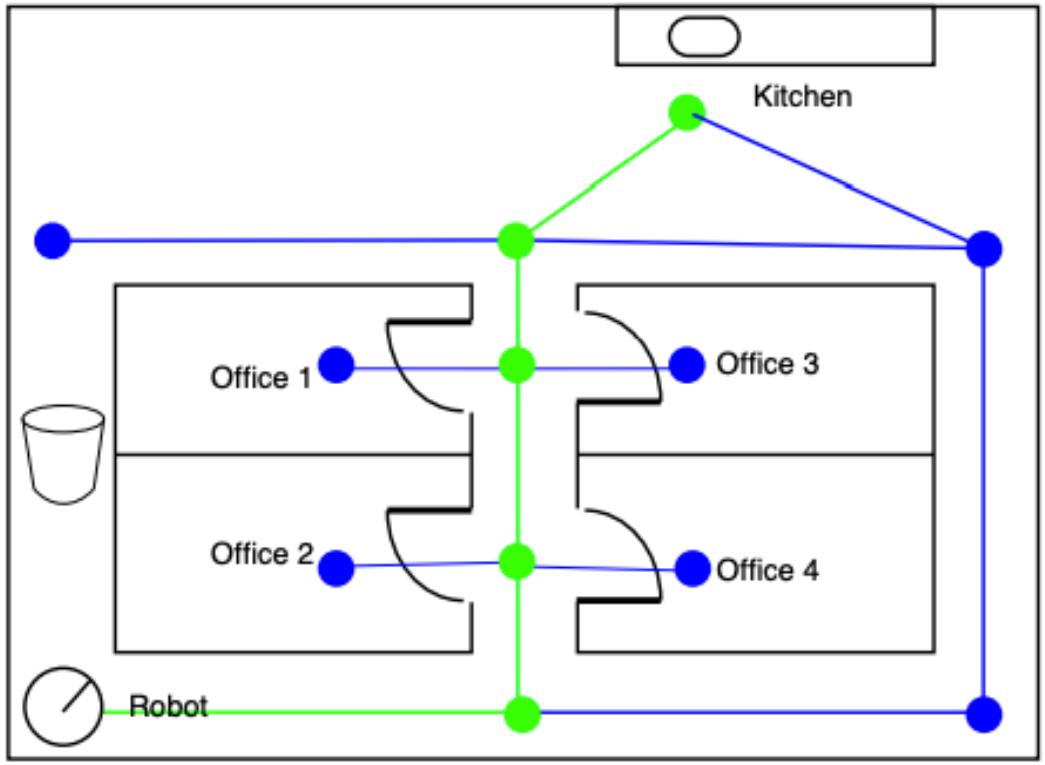
Path Planning



Path Planning

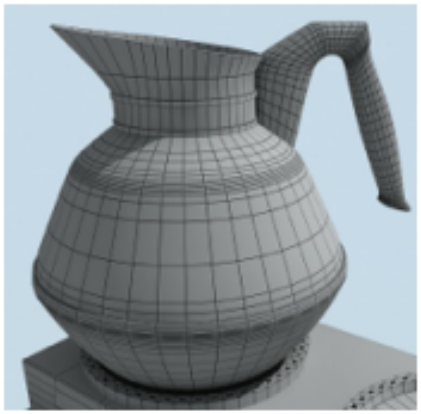


Path Planning

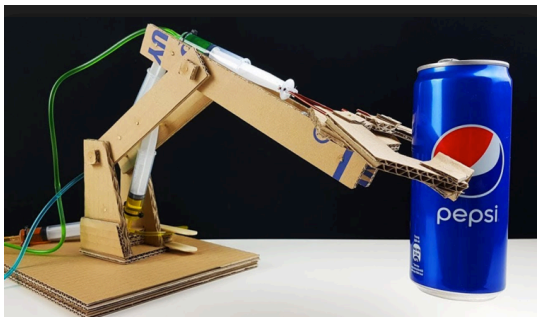


Computer Vision

Computer Vision



Robot Manipulation



- Robot state at time t : $\theta_t \in \mathbb{R}^7$ (7 joint angles)
- Goal: Plan a sequence of joint angles $\theta_1, ...\theta_7$ that move the manipulator from it's starting position around the handle of the coffee pot, without colliding with the environment

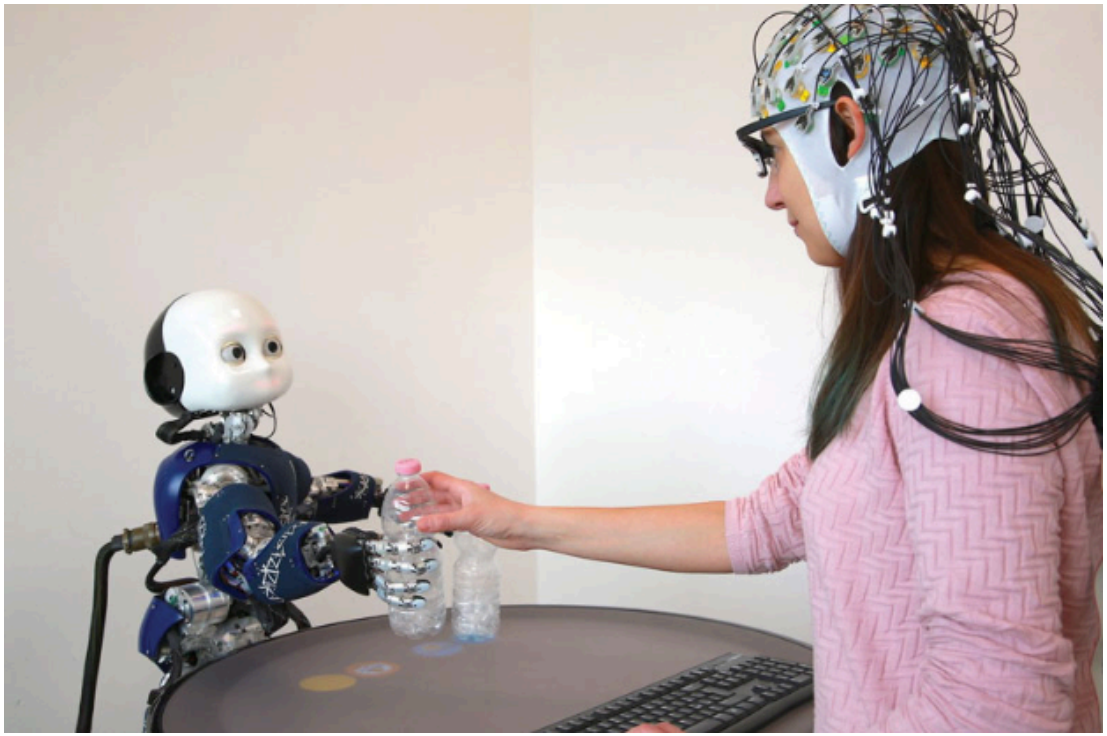
Reinforcement Learning

- Difficult to know precise physics to ensure that robot motion will not spill coffee
- Reinforcement learning approach:
  - Robot arrives without coffee spilled: Good robot!
  - Robot spills coffee: Bad robot!

Scheduling

Peter: Bring a cup of coffee to my office in 15 minutes
Richard: I need copies of the class project writeups before 1:20
Renjie: Meet me on the third floor of gates at 1:10, I will need your help for 15 minutes

Computational Game Theory



A "Simple" Task: Retated Areas of AI Research

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2. Probablistic Modeling, Bayesian Networks
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6. Computer Vision
7. Robot Manipulation
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...

Unlimited domains and applications

1. Computational Social Science
2. Computational Behavioural Science
3. Computational Psychology
4. Society Simulation
5. Data-driven Law
6. AI government
7. Intelligent Tutoring System
8. Educational Data Mining
9. Recommendation Systems
10. Anomaly Detection
11. Integer Programming

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Outline

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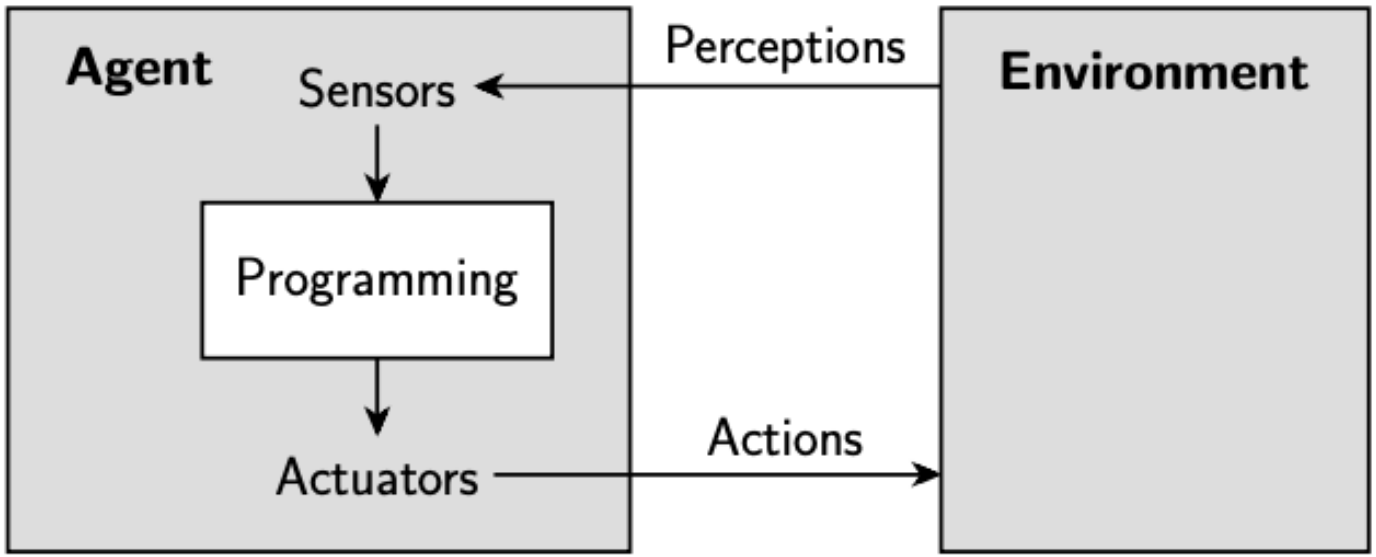
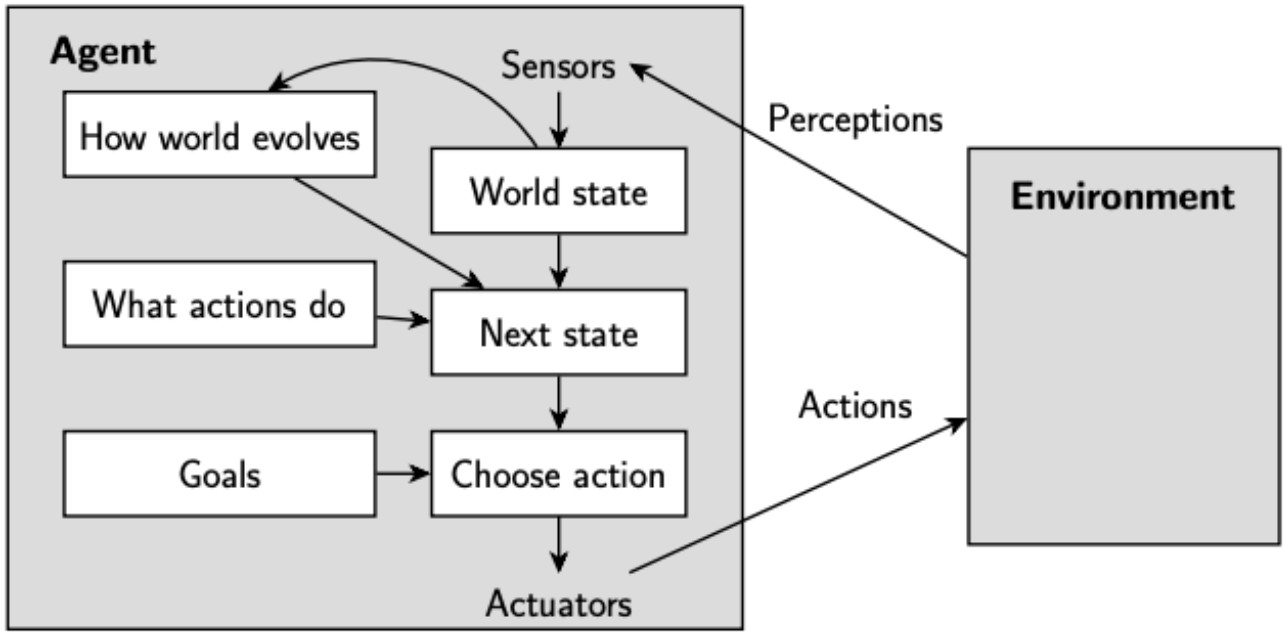
Generic Agent Architecture



Model-based, Goal-oriented Agent Architecture

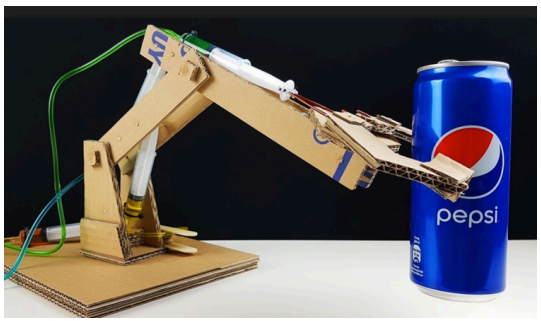


An Alternative Paradigm: Optimization

- Variables x, objective f, and constraints C
- Optimization problems have the form

$$\begin{aligned} \underset{x}{\text{minimize}} \quad & f(x) \\ \text{subject to} \quad & x \in C. \end{aligned}$$

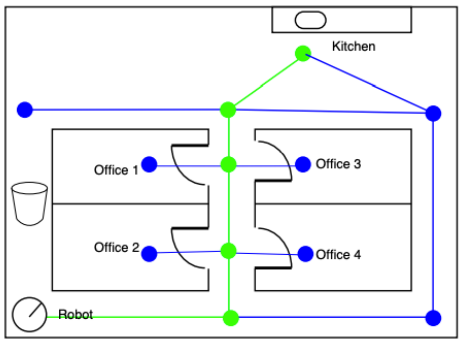
Robot Manipulation



- Robot state at time t : $\theta_t \in \mathbb{R}^7$ (7 joint angles)
- Goal: Plan a sequence of joint angles $\theta_1, ...\theta_7$ that move the manipulator from it's starting position around the handle of the coffee pot, without colliding with the environment

$$\begin{aligned} \underset{x}{\text{minimize}} \quad & \Sigma_{t=1}^{(T-1)} ||\theta_{t-a} - \theta_t||_2^2 \\ \text{subject to} \quad & \theta_t \in \mathbb{R}^7, t = 1, ..., T. \end{aligned}$$

Path planning



- Set of vertices $V = \{1, ..., n\}$, edge costs $C(i, j)$ (infinite if no edge between i and j)

$$\underset{x}{\text{minimize}} \quad \Sigma_{i=1}^{(L-1)} C(v_i, v_{i+1})$$

$$\text{subject to} \quad v_1 = \text{start}, v_L = \text{end}.$$

Machine Learning

- Common machine learning setup: inputs x_i, outputs y_i, $i = 1, ..., m$, hypothesis function $h(x_i)$
- Goal is to achieve $y_i \approx h(x_i)$

$$\underset{x}{\text{minimize}} \quad \sum_{i=1}^{m} (y_i - h_\theta(x_i))^2$$

AI in Social Sciences

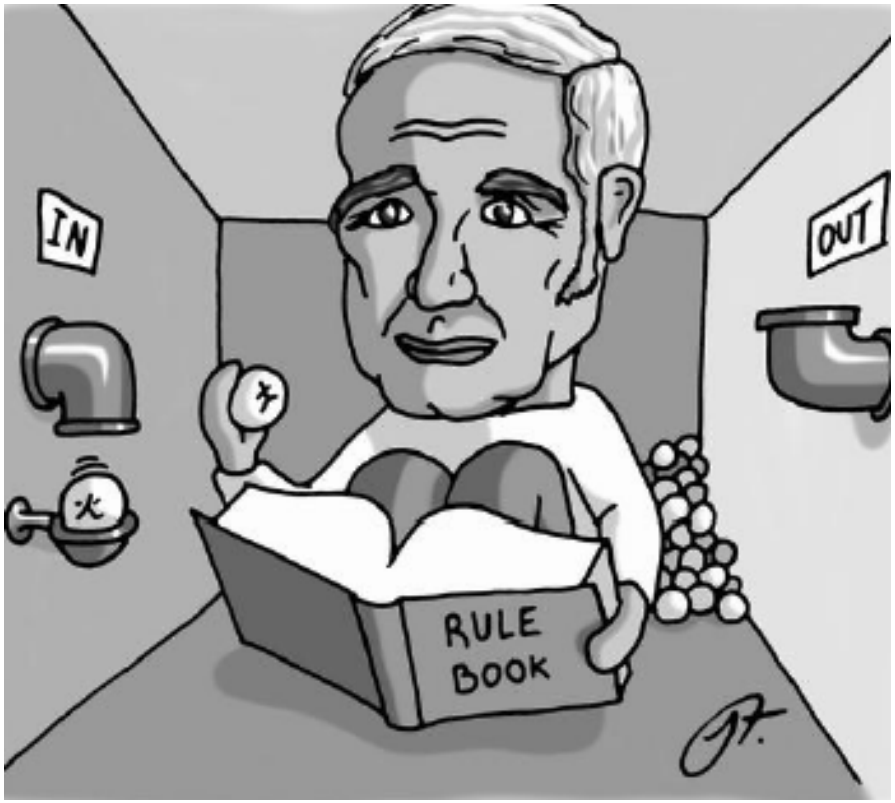
More details if there is time!

Outline

The Core Themes

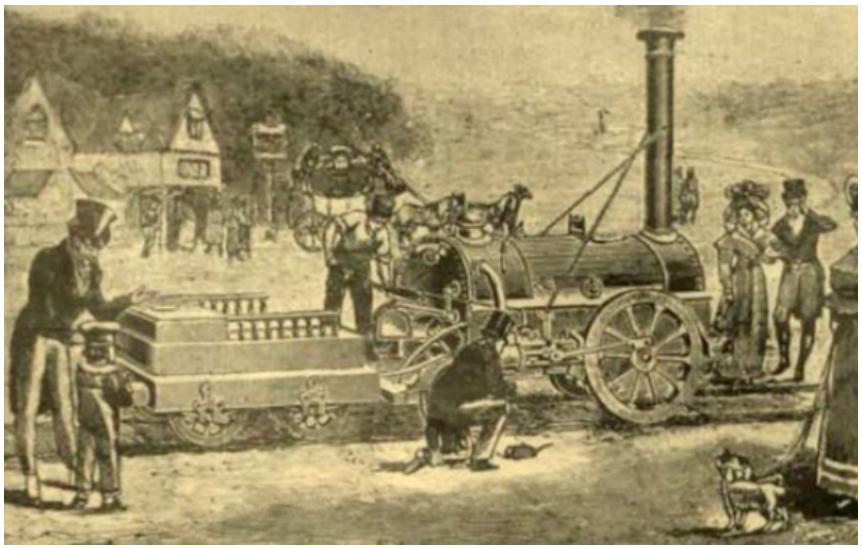
Smart software	Cognitive modeling
Symbolic AI	Neural nets
Reasoning	Perception
Reasoning	Knowledge
To represent	No need
Brain in a vat	Embodied AI
Narrow AI	Human-level intelligence

The Chinese Room

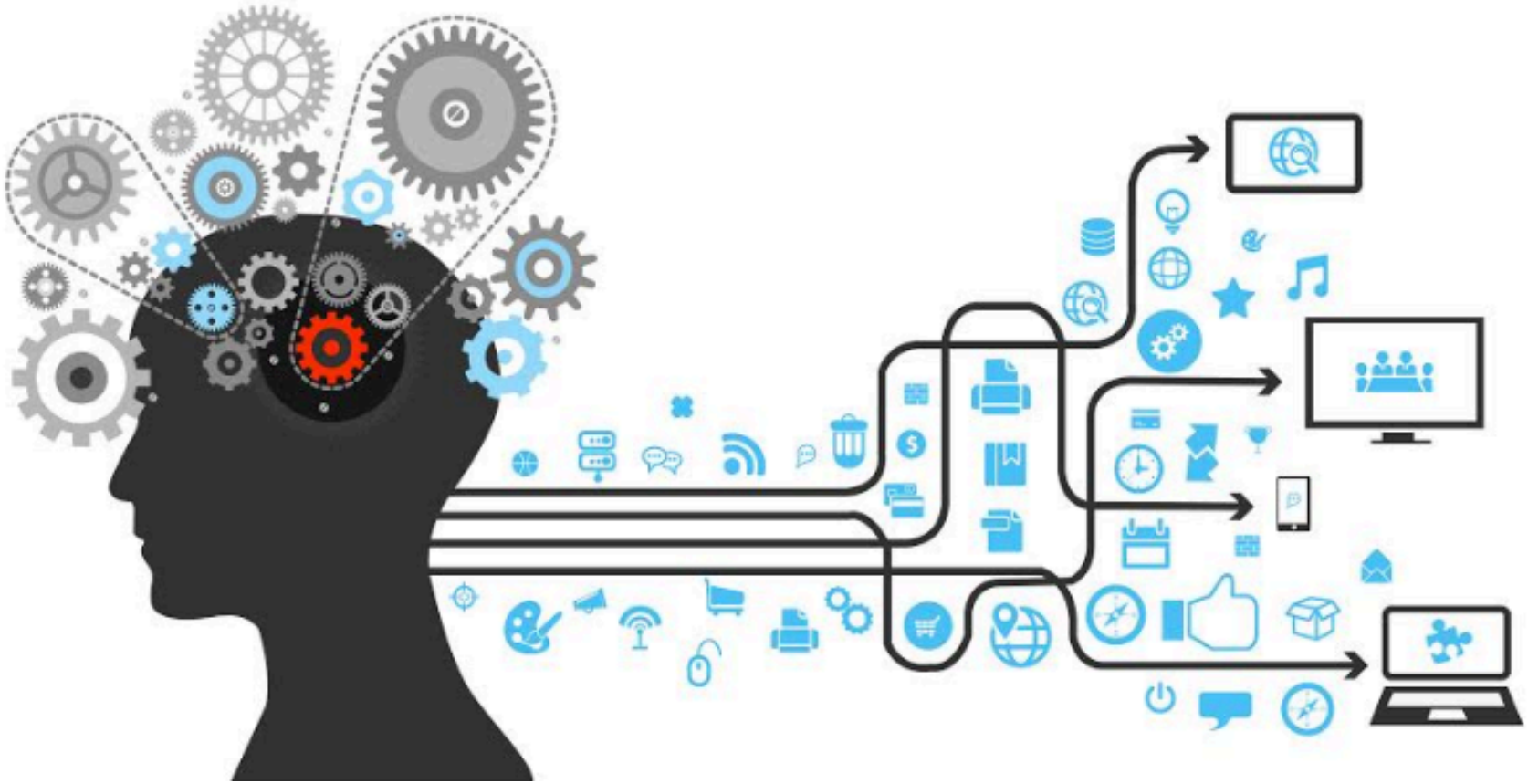


1. Suppose AI has produced a program that can pass the Turing Test in Chinese
2. You have a handbook with its pseudocode
3. You're in a closed room and receive Chinese characters through a slot
4. You run the program's code manually and return the output
5. Does this mean you understand Chinese?

The Big Picture: Revolution, Revolution



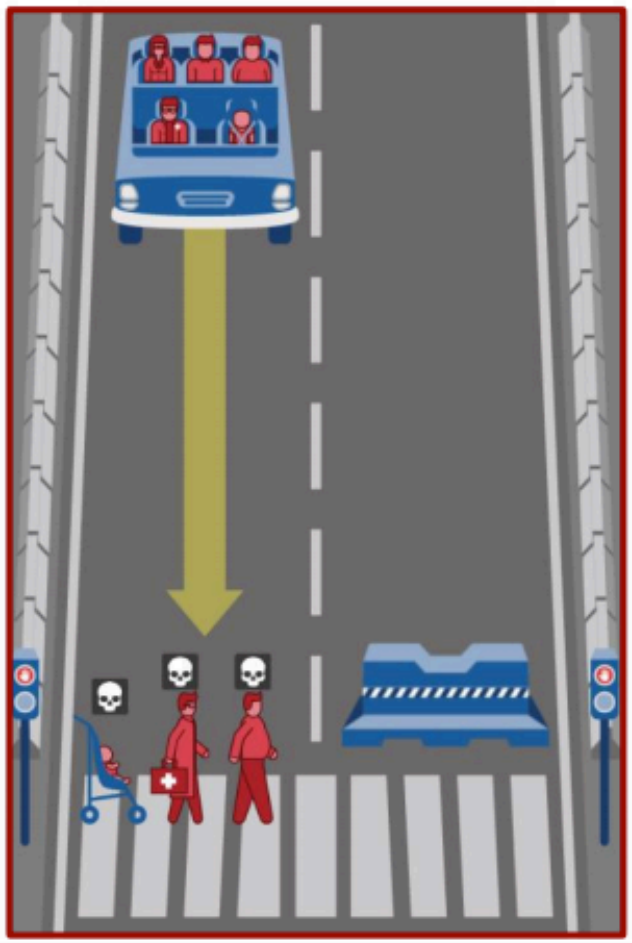
And...Revolution!

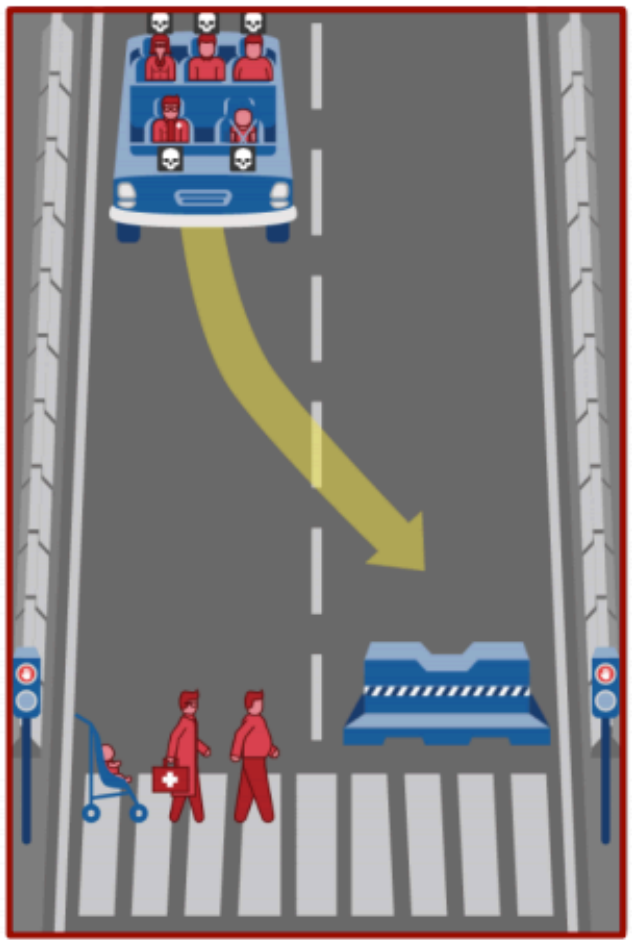


AI Safety

1. **Elon Musk**: AI is "our greatest existential threat"
2. **Stephen Hawking**: "Success in creating AI would be the biggest event in human history. Unfortunately, it might also be the last..."
3. **Bill Gates**: "First, the machines will do a lot of jobs for us and not be super intelligent. That should be positive if we manage it well. A few decades after that, though, the intelligence is strong enough to be a concern."

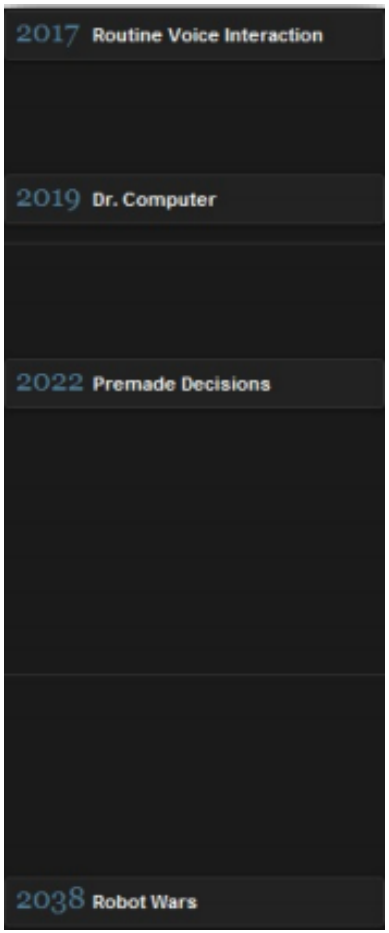
AI Ethics

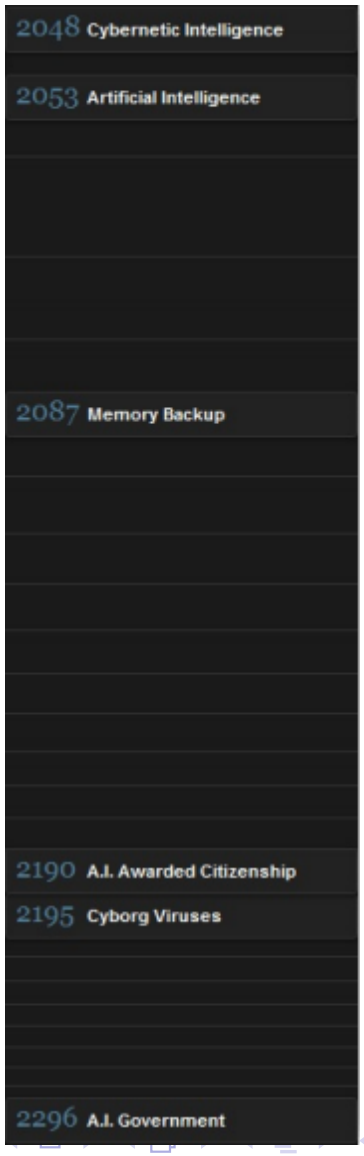




The Big Plus

The Future


2017 Routine Voice Interaction
2019 Dr. Computer
2022 Premade Decisions
2038 Robot Wars


2048 Cybernetic Intelligence
2053 Artificial Intelligence
2087 Memory Backup
2190 A.I. Awarded Citizenship
2195 Cyborg Viruses
2296 A.I. Government

The Technilogical Singularity

1. Emergence of superhuman intelligence
2. Key idea: self-improvement
3. The singularity is the point at which computers are smart enough to design smarter computers
4. Some predict: this century
5. Others argue: never

Some Parting Thoughts

1. "Computers in the future may have only 1,000 vacuum tubes and weigh only 1.5 tons."
   - Popular Mechanics, 1949
2. "Machines will be capable, within twenty years, of doing any work a man can do."
   - Herbert Simon, 1965

References

1. Zico Kolter's slides on artificial intelligence
   - http://www.cs.cmu.edu/~zkolter/course/15-780-s14/intelagents.pdf
   - http://www.cs.cmu.edu/~zkolter/course/15-780-s14/intro.pdf