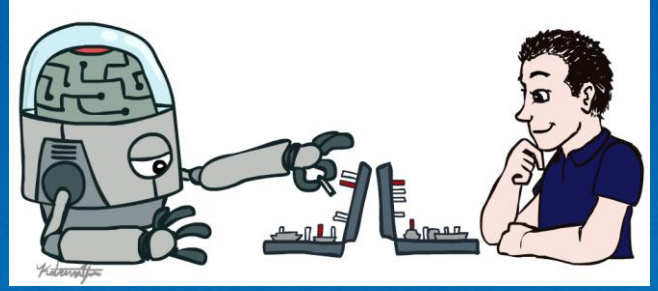


(some slides adapted from http://aima.cs.berkeley.edu/)

innovate achieve lead

BITS Pilani
Pilani Campus

DSE CL 557 - Artificial and Computational Intelligence

#1. Introduction

Sunday, August 30, 2020

Dr. Saikishor Jangiti

Agenda

(1) What is Artificial Intelligence?

i. Acting Humanly

ii. Thinking Humanly,

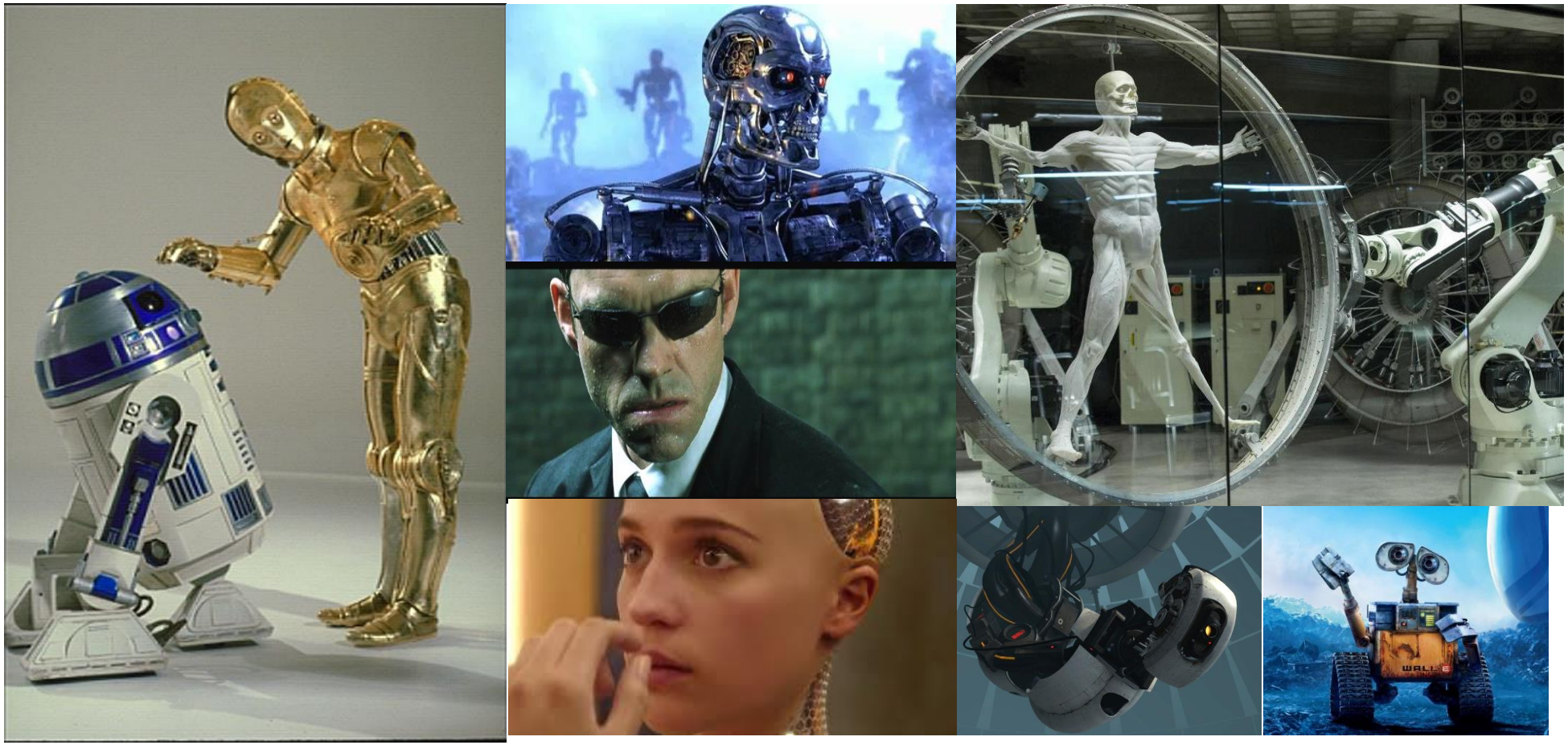
iii. Thinking Rationally,

iv. Acting Rationally

(2) Foundations of AI

(3) Brief Overview of Modern AI & Application Domains.

Sci-Fi AI?



Autonomous cars

Robots help nurses in hospitals deliver stuff to different rooms

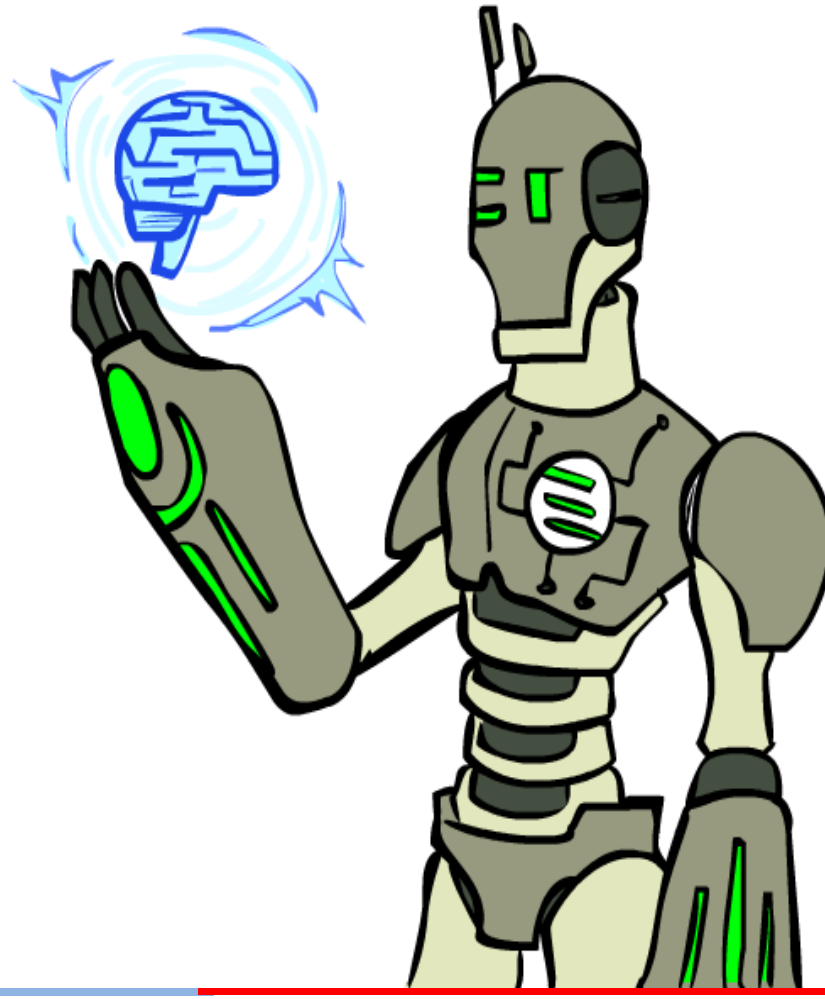
Drones that record cool videos

Autonomous Vacuum Cleaner

A Robot Learning on it's own

Today

- What is artificial intelligence?
- Where did it come from / What can AI do?
  - What should we and shouldn't we worry about? What can we do about the things we should worry about?
- What is this course?



Artificial Intelligence

- Term coined by, *John McCarthy* (1955) & *Dartmouth Summer Research Project on Artificial Intelligence* (1956)

On September 2, 1955, the project was formally proposed by McCarthy, Marvin Minsky, Nathaniel Rochester and Claude Shannon. The proposal is credited with introducing the term 'artificial intelligence'.

The Proposal states[7]

> 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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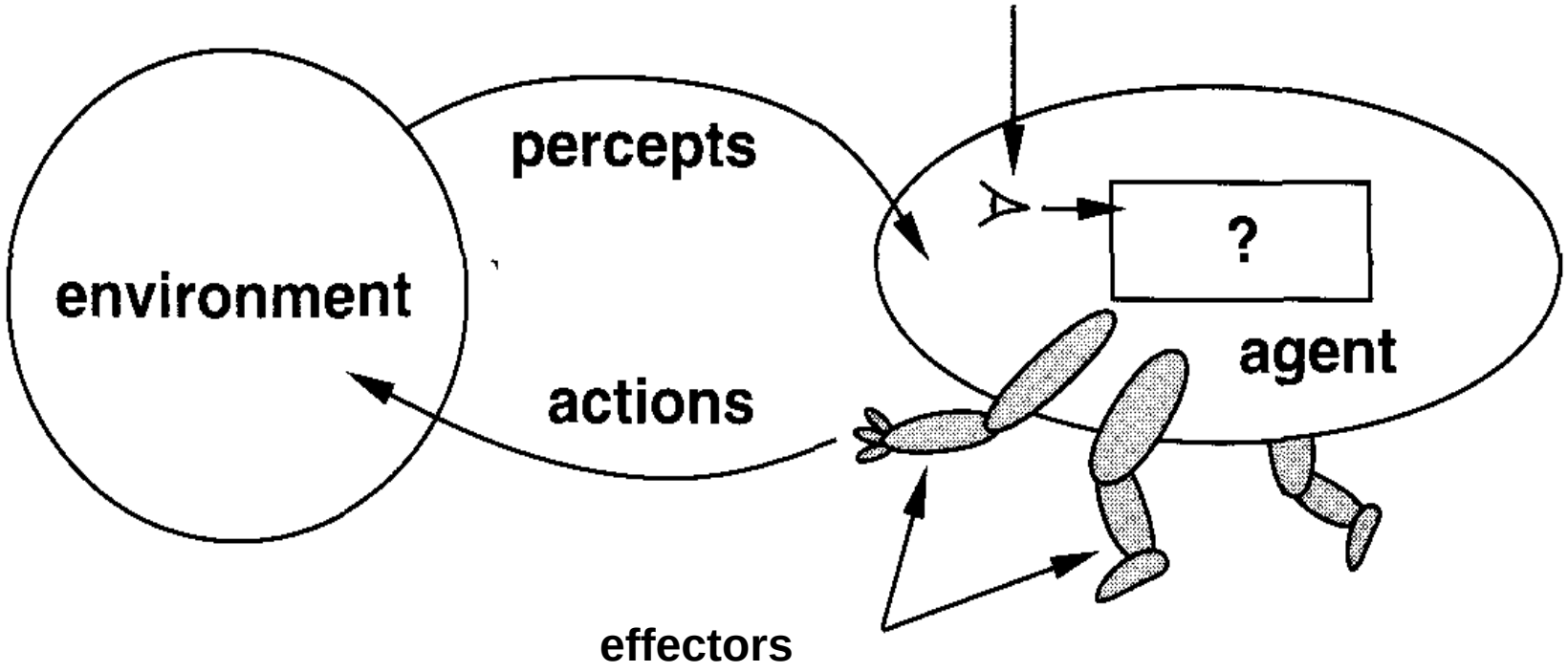
https://en.wikipedia.org/wiki/Dartmouth_workshop [01 June, 2019]

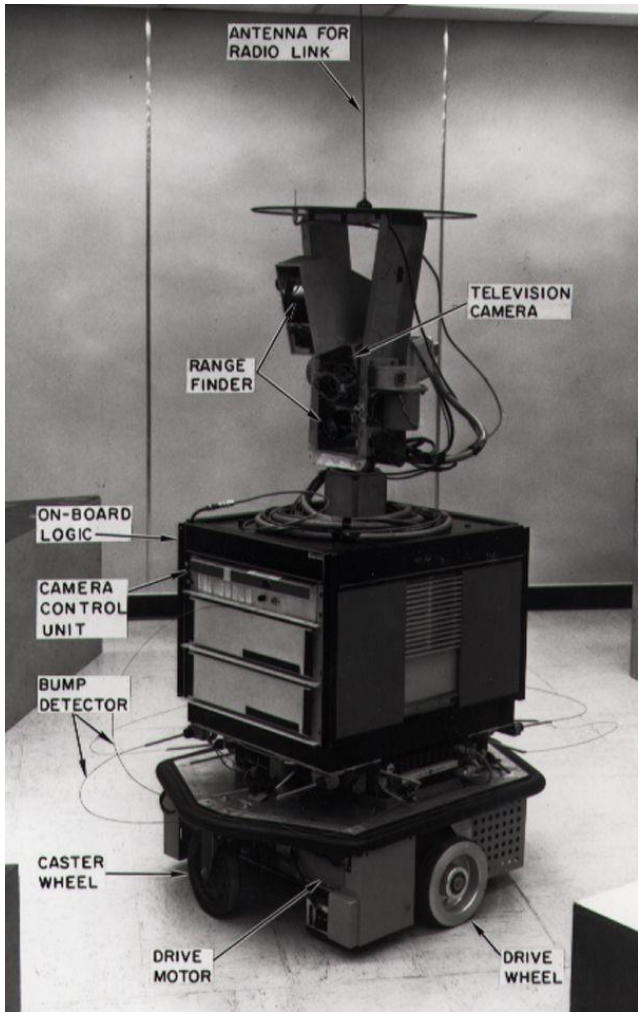
Larger Intent, Dream, Overconfidence ...

Intelligent Agents



Some Early successes of Dartmouth

- Many key projects were initiated after dartmouth summer project.
  a. Shakey robot - First mobile robot to perceive environment & reason about surroundings, actions - Introduced A* algorithm to find paths - Hough Transform for image analysis - Used Lisp for programming - visibility graph used for finding shortest paths in the presence of obstacles...



Some Early successes of Dartmouth

- Dendral -
  a. attempted to encode the domain expertise in molecular biology as an expert system
  b. Led to the creation of expert systems for various other domain, including medical.

- A milestone in the history of AI !!!

What is AI?

The science of making machines that:

Rational Decisions

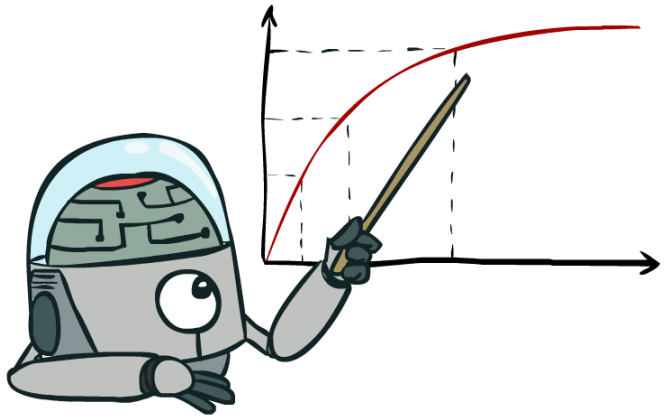
We'll use the term **rational** in a very specific, technical way:

- 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

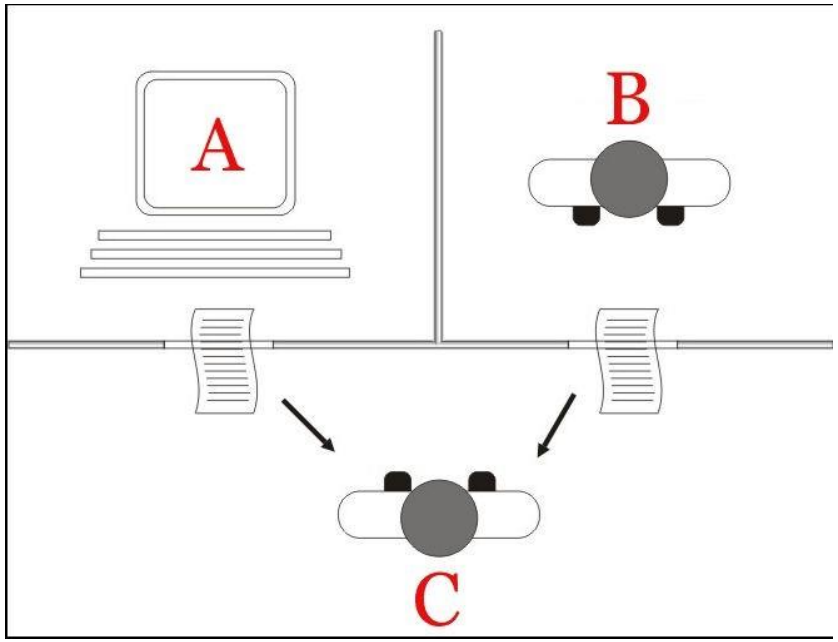
Maximize Your Expected Utility



Acting Humanly

Turing Test Approach

- *Turing Test* & *Total turing test* (operational test to determine an entity is intelligent / not) [50's]
- Skills necessary to pass these tests
  - NLP, Knowledge Representation, Automated Reasoning, ML + Computer Vision & Robotics(for total turing test)



Pictorial Representation of Turing Test from https://en.wikipedia.org/wiki/Turing_test

Acting Humanly

Turing Test Approach

Some Definitions of AI:

"The art of creating machines that perform functions that require intelligence when performed by people." (Kurzweil, 1990)

"The study of how to make computers do things at which, at the moment, people are better." (Rich and Knight, 1991)

Thinking Humanly

Cognitive Modelling Approach

- How do we capture human thinking to implement
  - Introspection
  - Psychological Experiments
  - Brain Imaging
- System : *"General Problem Solver"* (*Newell and Simon, 1961*)
  - Designed to work as a universal problem solver
  - Problems represented by horn clauses
  - First AI Machine which has KB + Inference separation
  - Authors focus on this is on comparing the trace of its reasoning steps to traces of human subjects solving the same problems
- Growth of Cognitive science and AI supports each other

Thinking Humanly

Cognitive Modelling Approach

- Some Definitions of AI

"The exciting new effort to make computers think . . . machines with minds, in the full and literal sense." (Haugeland, 1985)

"[The automation of] activities that we associate with human thinking, activities such as decision-making, problem solv-ing, learning . . ." (Bellman, 1978)

Thinking Rationally

"Laws of Thought" Approach

- Invention of Formal Logic, Greek Philosopher Aristotle, Third century BC.
- Introduced syllogisms, providing argument structures

In all boring classes, students sleeps

Thinking Rationally

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Students sleeps in this class [Are you ?]

Thinking Rationally

"Laws of Thought" Approach

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In all boring classes, students sleep
It is a boring class
Students sleep in this class [Are you ?]

- Field of Logics gave rise to codifying rational thinking
  - When elements are '*things*', we reason about things

Hurdles to the idea : (1) Not everything can be logically coded (2) no provably correct action at a moment (3) Exhaustive computational resources

Acting Rationally

The Rational Agent Approach

- An agent is an entity that perceives and acts
- *This course is about designing rational agents*
- Abstractly, an agent is a function from percept histories to actions:

  [f: P* → A]
- For any given class of environments and tasks, we seek the agent (or class of agents) with the best performance
- Computational limitations make perfect rationality unachievable
- Design best program for given machine resources

Acting Rationally

The Rational Agent Approach

- Rational behavior: doing the *right thing*
- The *right thing:* that which is expected to maximize goal achievement, given the available information
- Rational behaviour is not just about correct inference / thinking, skills needed to pass turing test etc.
- (adv) : More General - Correct inference is just a thing
- (adv) : More amenable for scientific developments, as the rational behaviour is better defined than human thinking and behavior

(aside) Passing the Turing Test

Transcript of a chat

EUGINE - a thirteen-year-old Ukrainian boy, chats

JUDGE: Hello.
EUGENE: Hello, I'm really glad to have the chance to chat with you! My guinea pig Bill sends his regards too!
JUDGE: Is Bill a male or a female?
EUGENE: Ask Bill personally, please.
JUDGE: Well I'd rather talk to you. What is your name?
EUGENE: Call me Eugene. I am glad to talk to you!
JUDGE: My name is Jane and I am female. How about you? What's your gender?
EUGENE: I'm a male. A “guy’ I'd say.
JUDGE: Pleased to meet you Eugene. What's the weather like where you are?
EUGENE: Let's get on with our conversation!
JUDGE: Don't you like talking about the weather?
EUGENE: All these talks about weather is a waste of time.
JUDGE: What would you like to discuss?
EUGENE: I don't know. Better tell me more about yourself!

(aside) Passing the Turing Test

- 2014 - Royal Society (London) - Sixteenth Anniversary of Alan Turing -
- Chatbot - Eugene Goostman- Pretended to be a thirteen-year-old Ukrainian boy
  - Passed the turing test for the first time
  - 10/30 Judges believed the response is from human
- *Turing predicted in 50 years time, computers can be programmed to play imitation game in which an average interrogator fails to identify the machine 70% time in a 5 mins questioning*

About the course

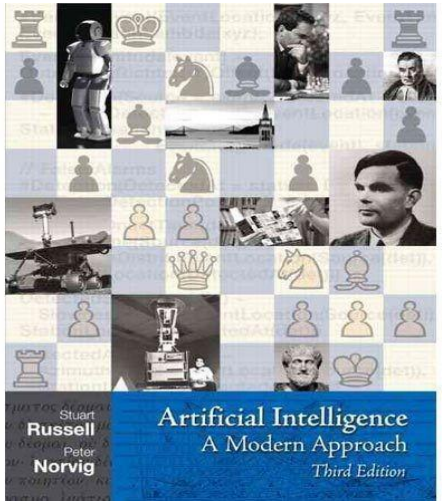
- Course focuses on
  - principles of artificial intelligence
  - concepts, algorithms involved in building rational agents
  - topics covered like
    - (informed and uninformed) search & applications
    - (logical & probabilistic) knowledge representation
    - (logical & probabilistic) Reasoning & applications
    - a bit of learning (reinforcement learning)
  - topics not-covered like
    - Formal introduction to machine learning algorithms, neural networks etc are covered as a ML course is running in parallelly, Deep neural networks (deep learning course) , which are part of AI as well.

About the course and Evaluation

- Text Book
  AIMA – Artificial Intelligence – A Modern Approach

- Exercises : In Python & its libraries

- Evaluation :
  25% Assignment
  + 5% Quiz
  + 30% Mid Semester
  + 40% End Semester

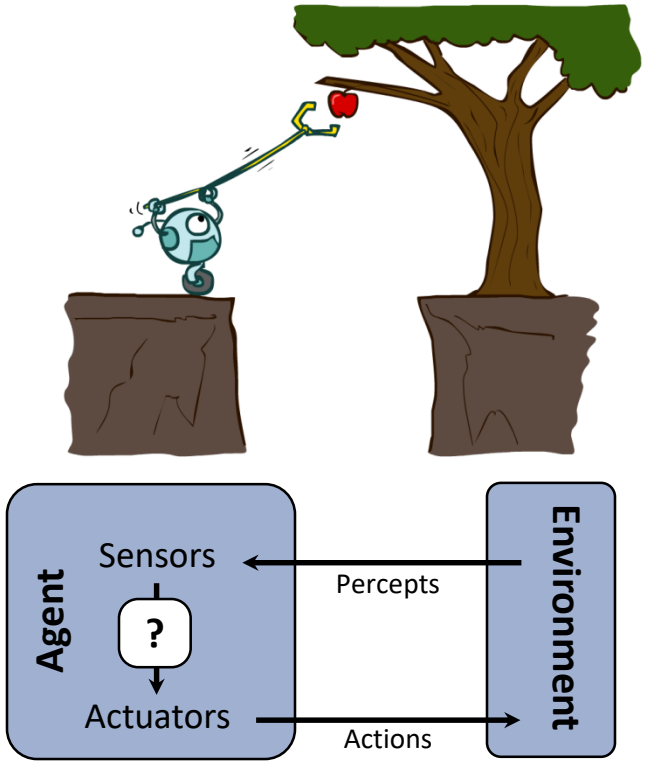


What About the Brain?

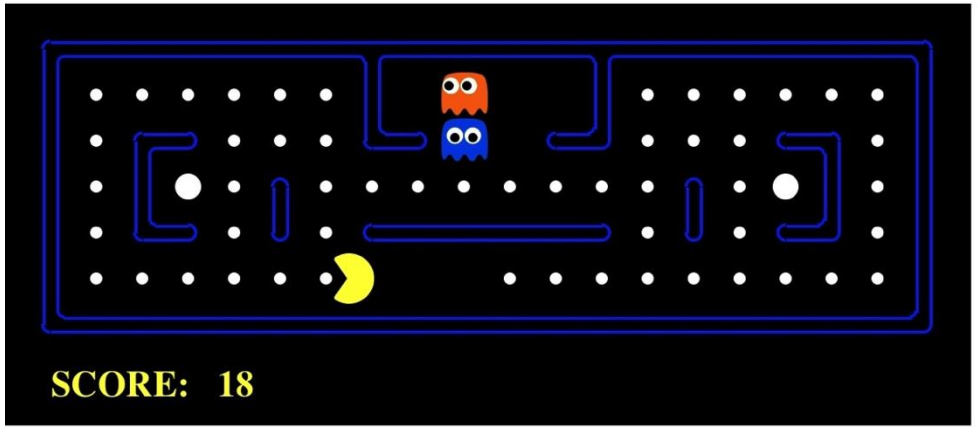
- Brains (human minds) are very good at making rational decisions, but not perfect
- Brains aren't as modular as software, so hard to reverse engineer!
- "Brains are to intelligence as wings are to flight"
- Lessons learned from the brain: memory and simulation are key to decision making

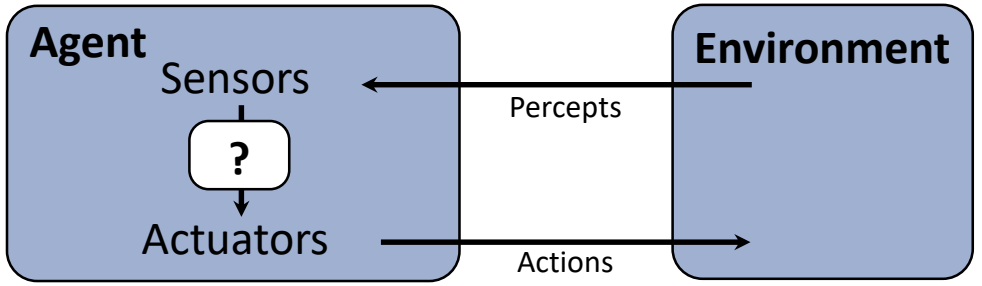
Designing Rational Agents

- 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



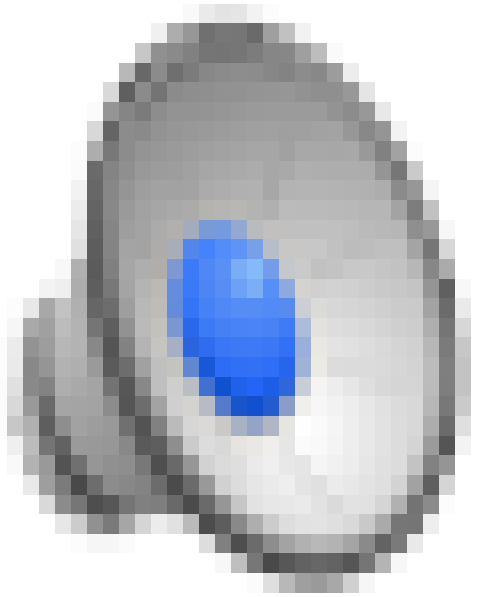
Pac-Man as an Agent



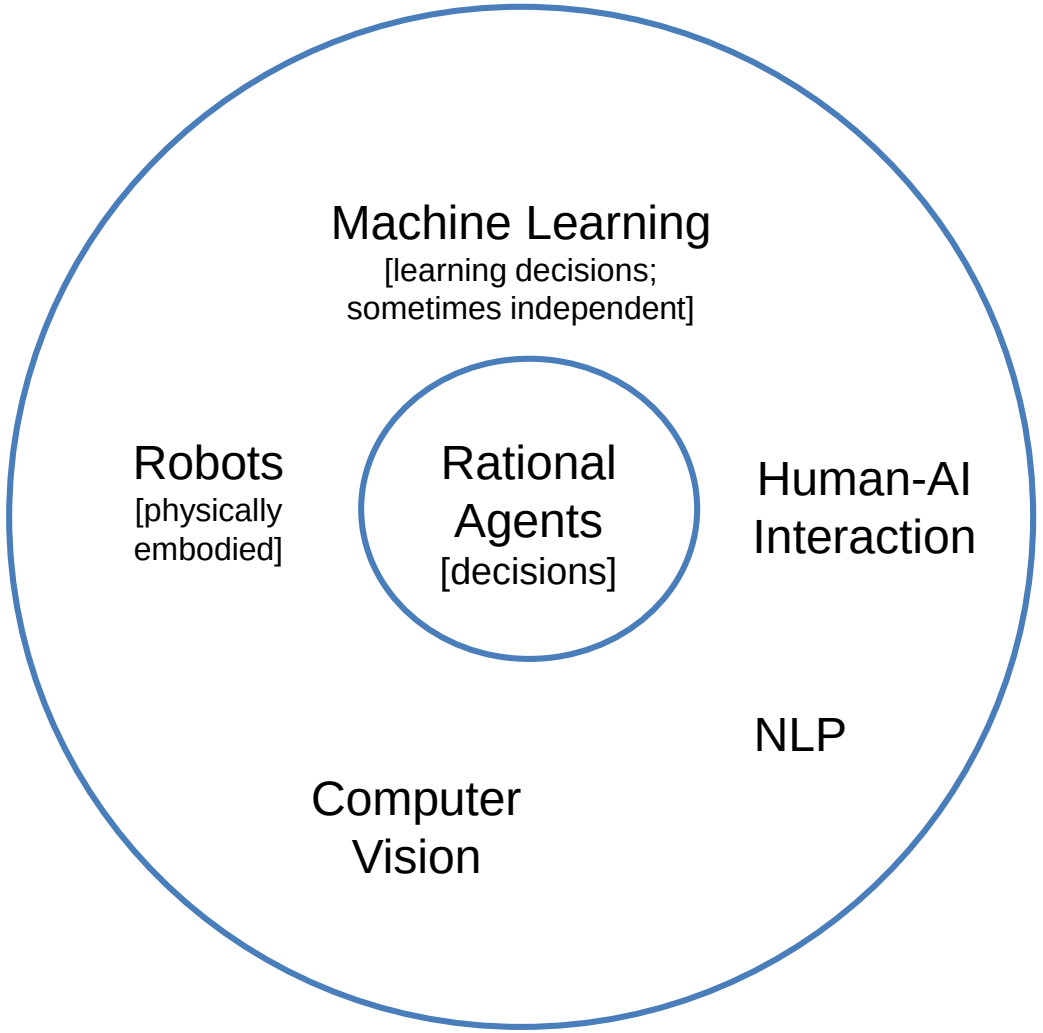


Pac-Man is a registered trademark of Namco-Bandai Games, used here for educational purposes

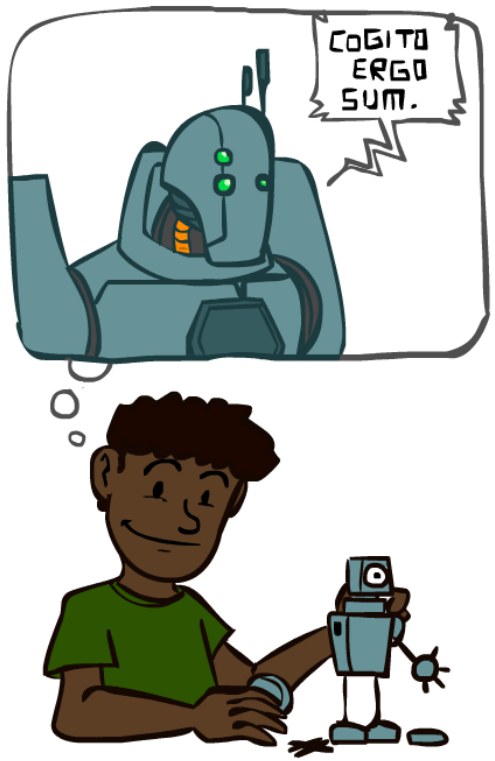
Demo1: pacman-l1.mp4

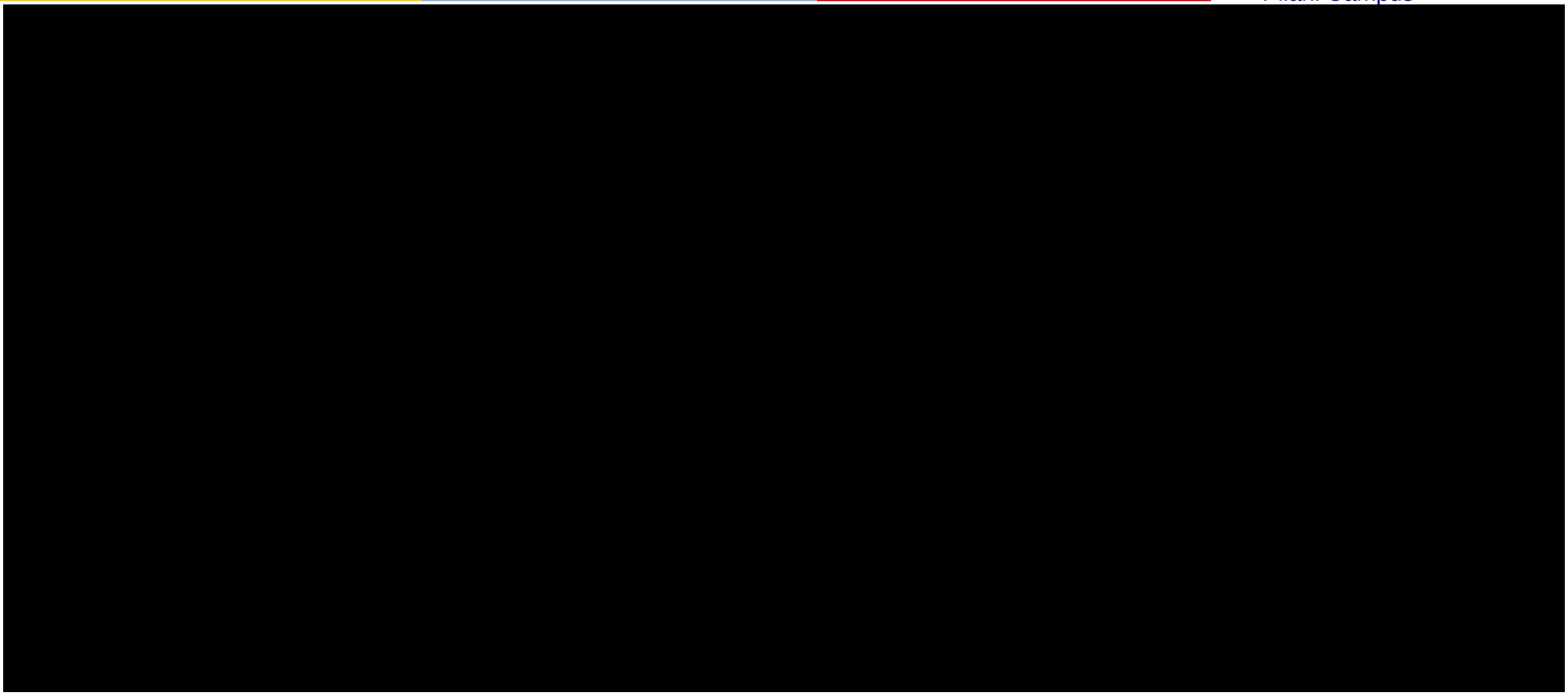


Artificial Intelligence



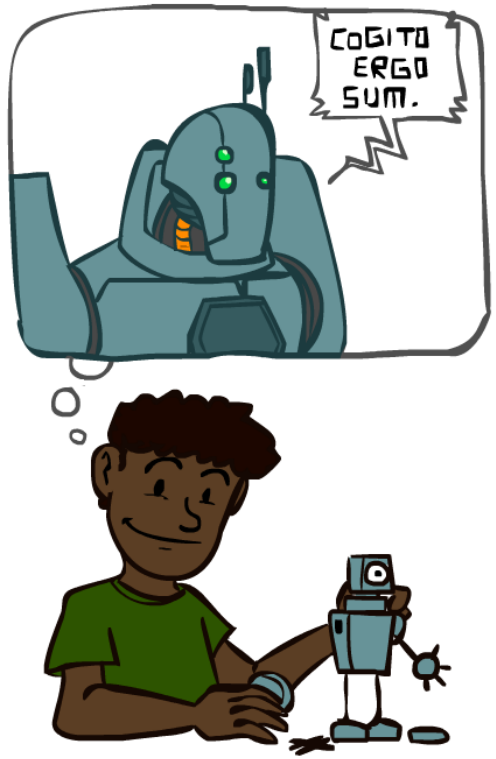
A (Short) History of AI





A (Short) History of AI

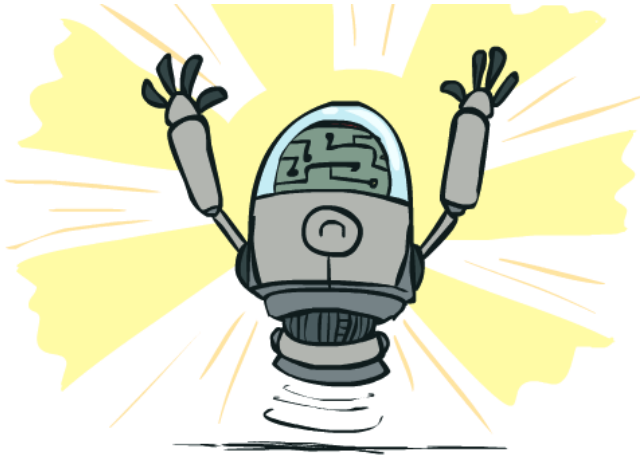
- 1940-1950: Early days
  - 1943: McCulloch & Pitts: Boolean circuit model of brain
  - 1950: Turing's "Computing Machinery and Intelligence"
- 1950—70: Excitement: Look, Ma, no hands!
  - 1950s: Early AI programs, including Samuel's checkers program, Newell & Simon's Logic Theorist, Gelernter's Geometry Engine
  - 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—: Statistical approaches
  - Resurgence of probability, focus on uncertainty
  - General increase in technical depth
  - Agents and learning systems… "AI Spring"?
- 2000—: Where are we now?



What Can AI Do?

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

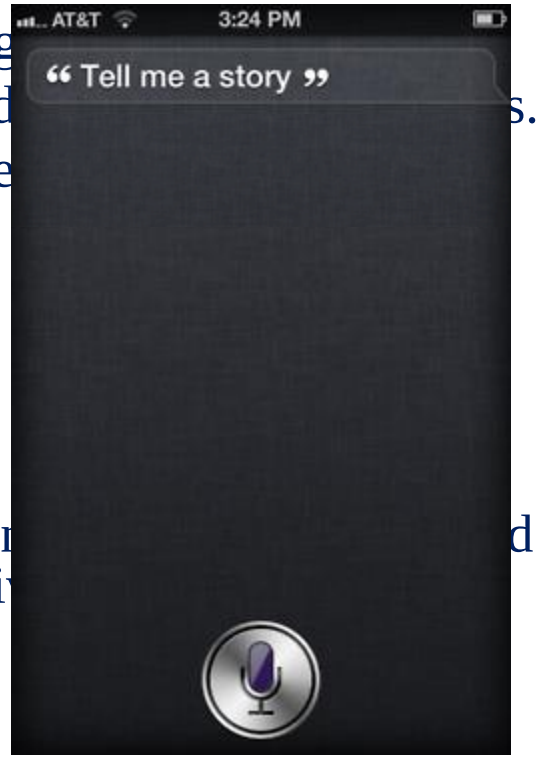
- ✓ Play a decent game of Jeopardy?
- ✓ Win against any human at chess?
- ✓ Win against the best humans at Go?
- ✓ Play a decent game of tennis?
- ✓ Grab a particular cup and put it on a shelf?
- ✗ Unload any dishwasher in any home?
- ✓ Drive safely along the highway?
- ✗ Drive safely along busy market street?
- ✓ Buy a week's worth of groceries on the web?
- ✗ Buy a week's worth of groceries at a supermarket?
- ? Discover and prove a new mathematical theorem?
- ? Perform a surgical operation?
- ✓ Translate spoken Hindi into spoken English in real time?
- ✗ Write an intentionally funny story?

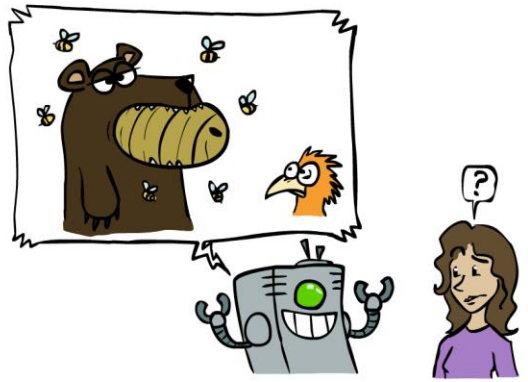


Unintentionally Funny Stories

- One day Joe Bear was hung

He asked his friend Irving Bird s.
Irving told him there was a bee
Joe walked to the oak tree.
He ate the beehive. The End.





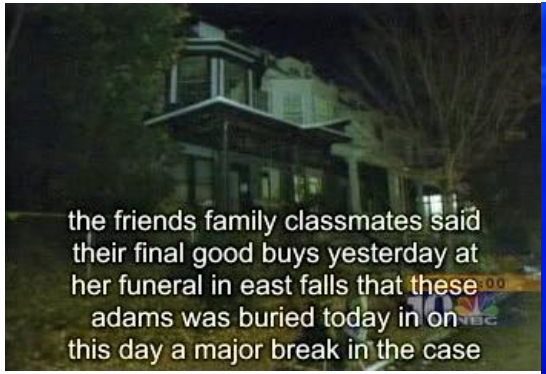
- Henry Squirrel was thirsty.

He walked over to the river ba d Bill Bird was sitting.
Henry slipped and fell in the ri
Gravity drowned. The End.

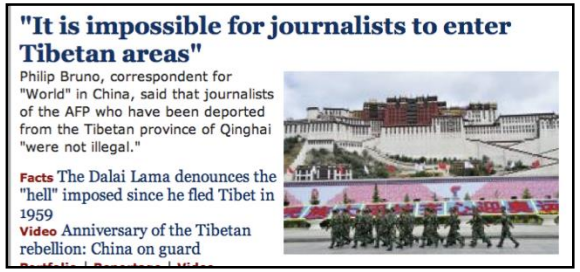
[Shank, Tale-Spin System, 1984]

Natural Language

- Speech technologies (e.g. Siri)
  - Automatic speech recognition (ASR)
  - Text-to-speech synthesis (TTS)
  - Dialog systems



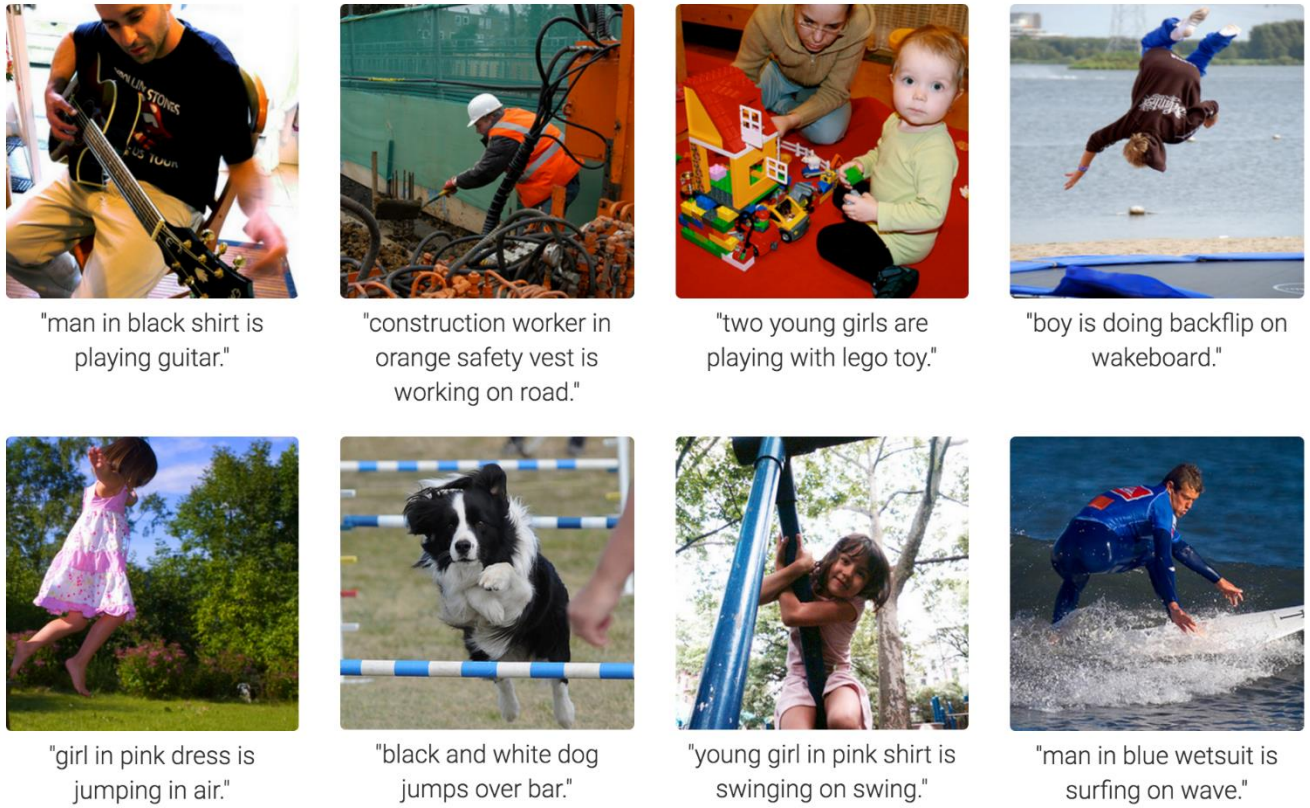
- Language processing technologies
  - Question answering
  - Machine translation



  - Web search
  - Text classification, spam filtering, etc…

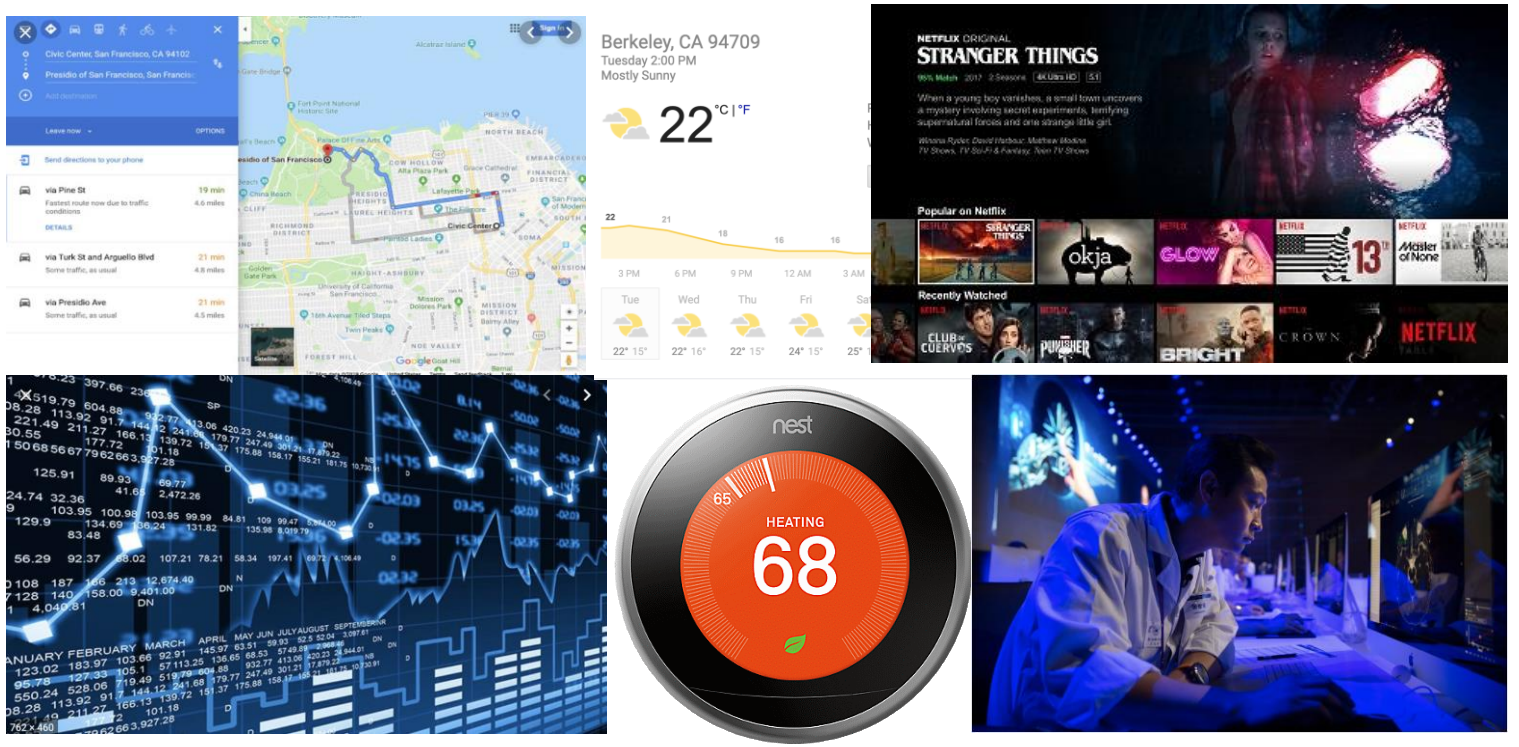
https://play.aidungeon.io/

Computer Vision



Karpathy & Fei-Fei, 2015; Donahue et al., 2015; Xu et al, 2015; many more

Tools for Predictions & Decisions



Game Agents

- Classic Moment: May, '97: Deep Blue vs. Kasparov
  - First match won against world champion
  - "Intelligent creative" play
  - 200 million board positions per second
  - Humans understood 99.9 of Deep Blue's moves
  - Can do about the same now with a PC cluster

- 1996: Kasparov Beats Deep Blue
  "I could feel --- I could smell --- a new kind of intelligence across the table."
- 1997: Deep Blue Beats Kasparov
  "Deep Blue hasn't proven anything."

Text from Bart Selman, image from IBM's Deep Blue pages

Game Agents

- Re


Photo: Google / Getty Images

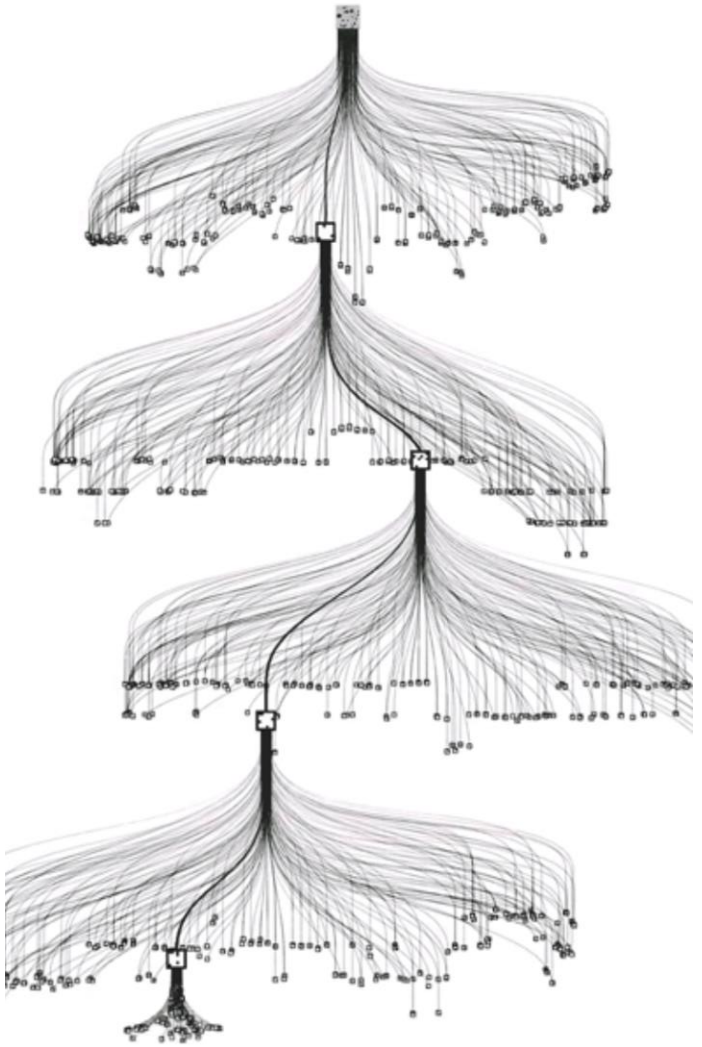
AlphaGo

- AlphaGo is the first computer program to defeat a professional human Go player
- Go originated in China over 3,000 years ago. Winning this board game requires multiple layers of strategic thinking.
- At the opening move in Chess there are 20 possible moves. In Go the first player has 361 possible moves
- Policy network -selects the next move to play.
- Value network predicts the game winner

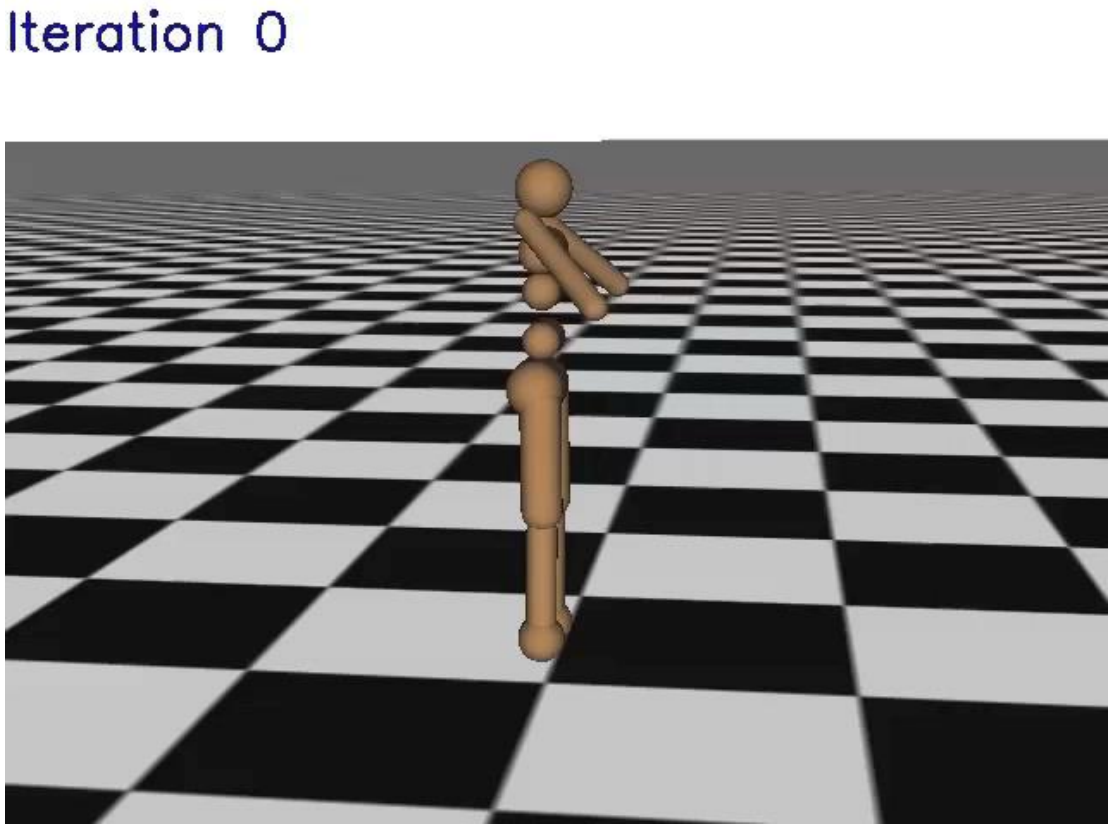
In late 2017, we introduced AlphaZero, a single system that taught itself from scratch how to master the games of chess, shogi, and Go, beating a world-champion program in each case.

AlphaGo

- AlphaGo must restrict Breath and Depth of search among all board configurations with heuristics information supplied by training and winning policy for max reward.



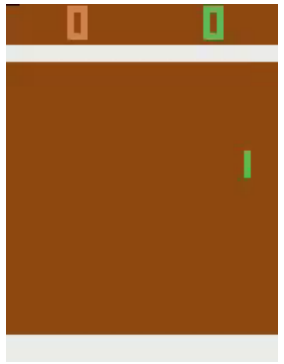
Simulated Agents



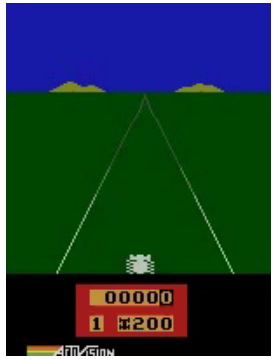
[Schulman, Moritz, Levine, Jordan, Abbeel, ICLR 2016]

Game Agents

- Reinforcement learning

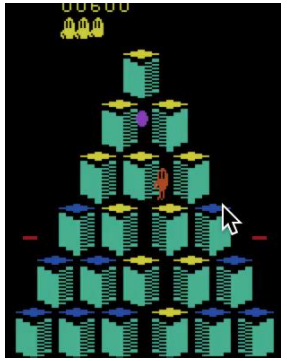


Pong



Enduro

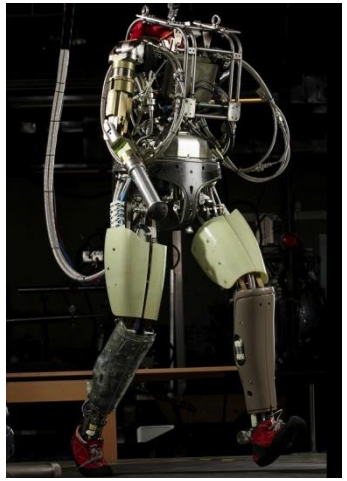
Beamrider



Q*bert

Robotics

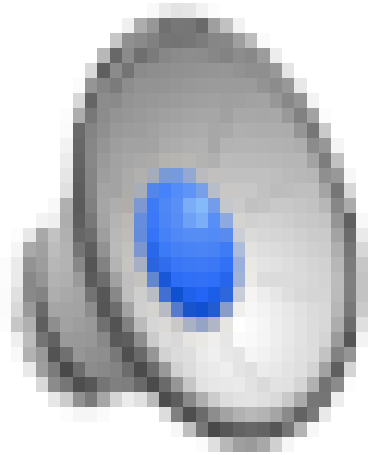
- Robotics
  - Part mech. eng.
  - Part AI
  - Reality much harder than simulations!
- Technologies
  - Vehicles
  - Rescue
  - Help in the home
  - Lots of automation…
- In this class:
  - We ignore mechanical aspects
  - Methods for planning
  - Methods for control



Images from UC Berkeley, Boston Dynamics, RoboCup, Google

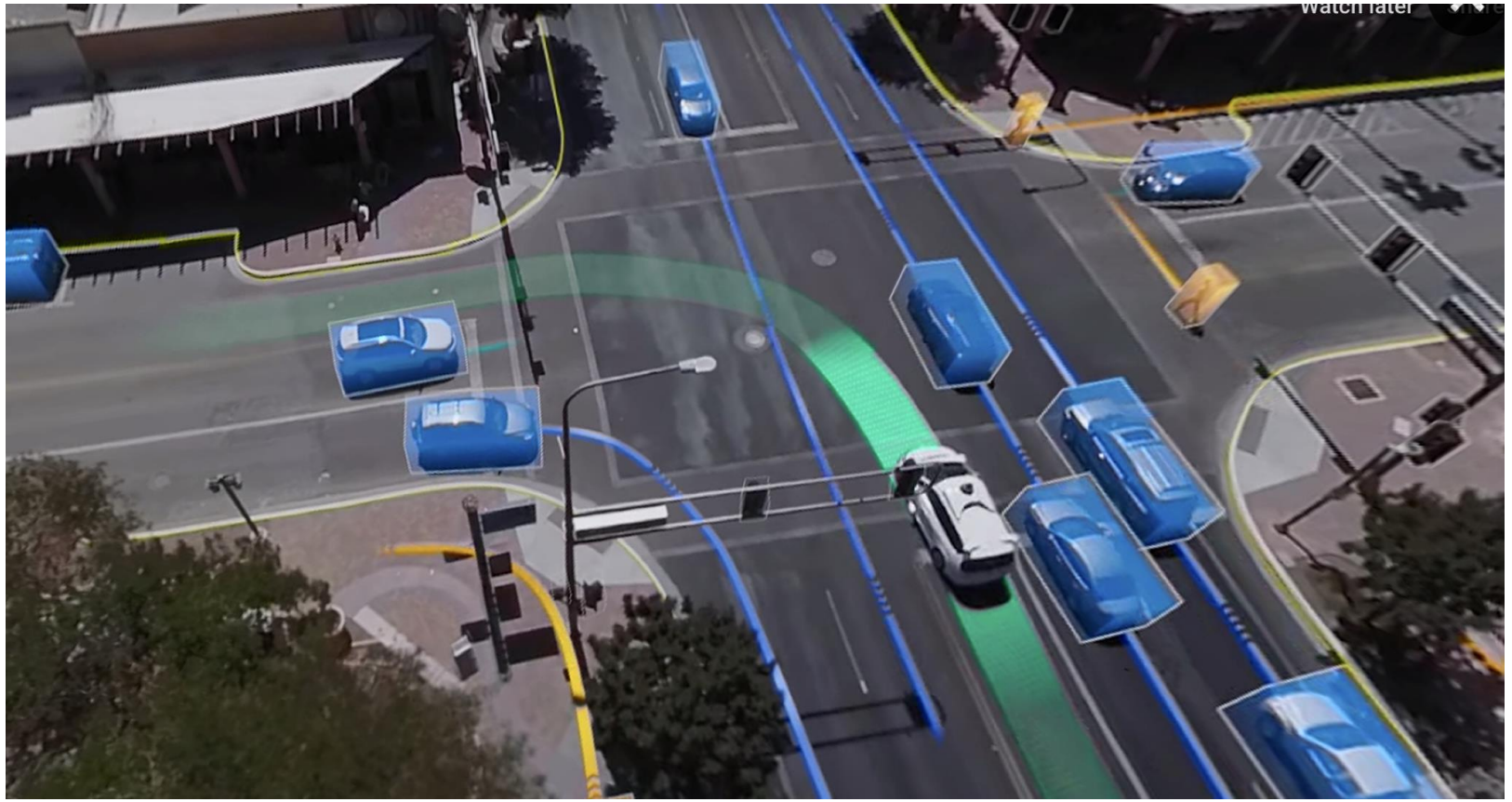
Robots

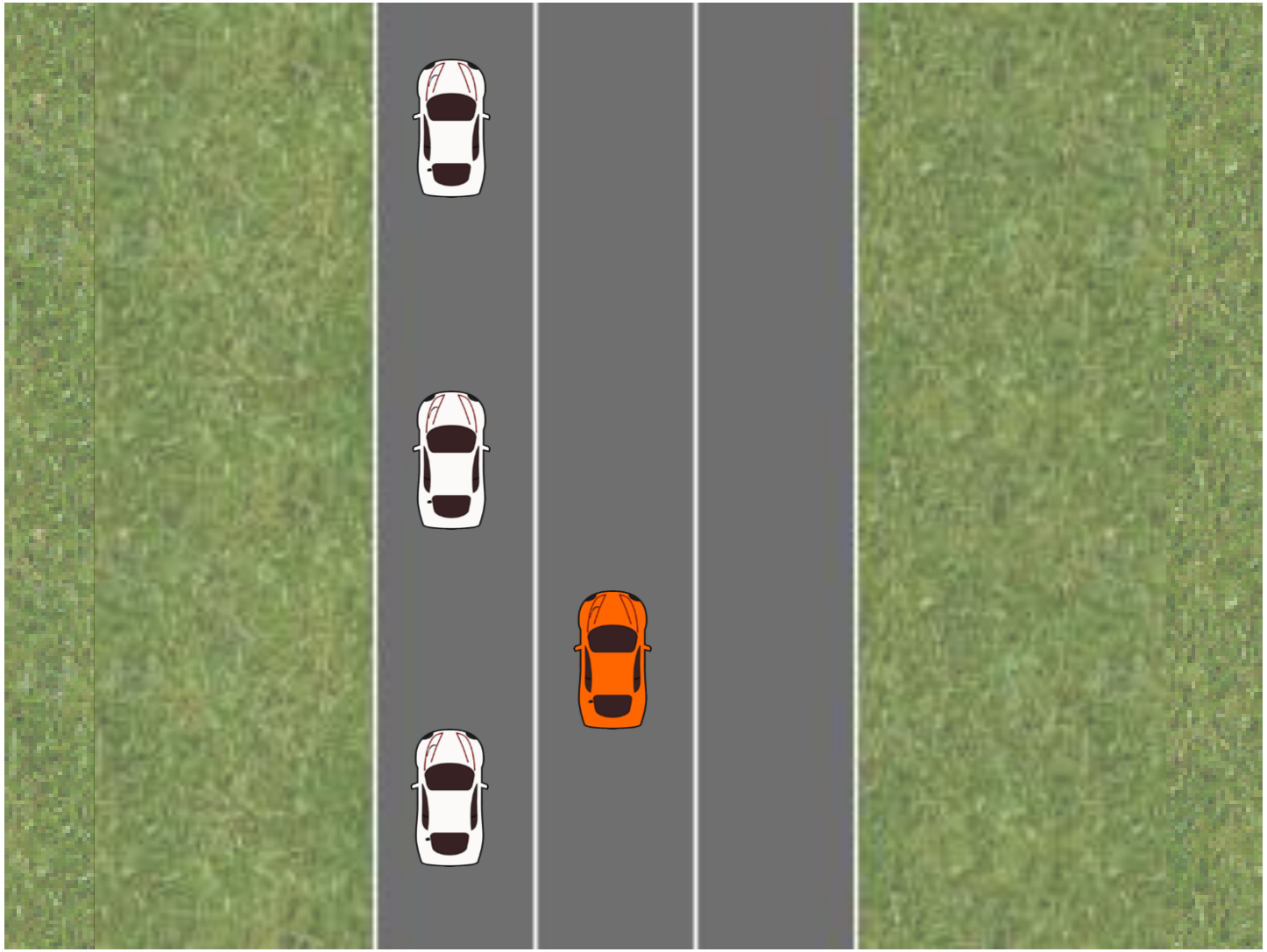
Robots

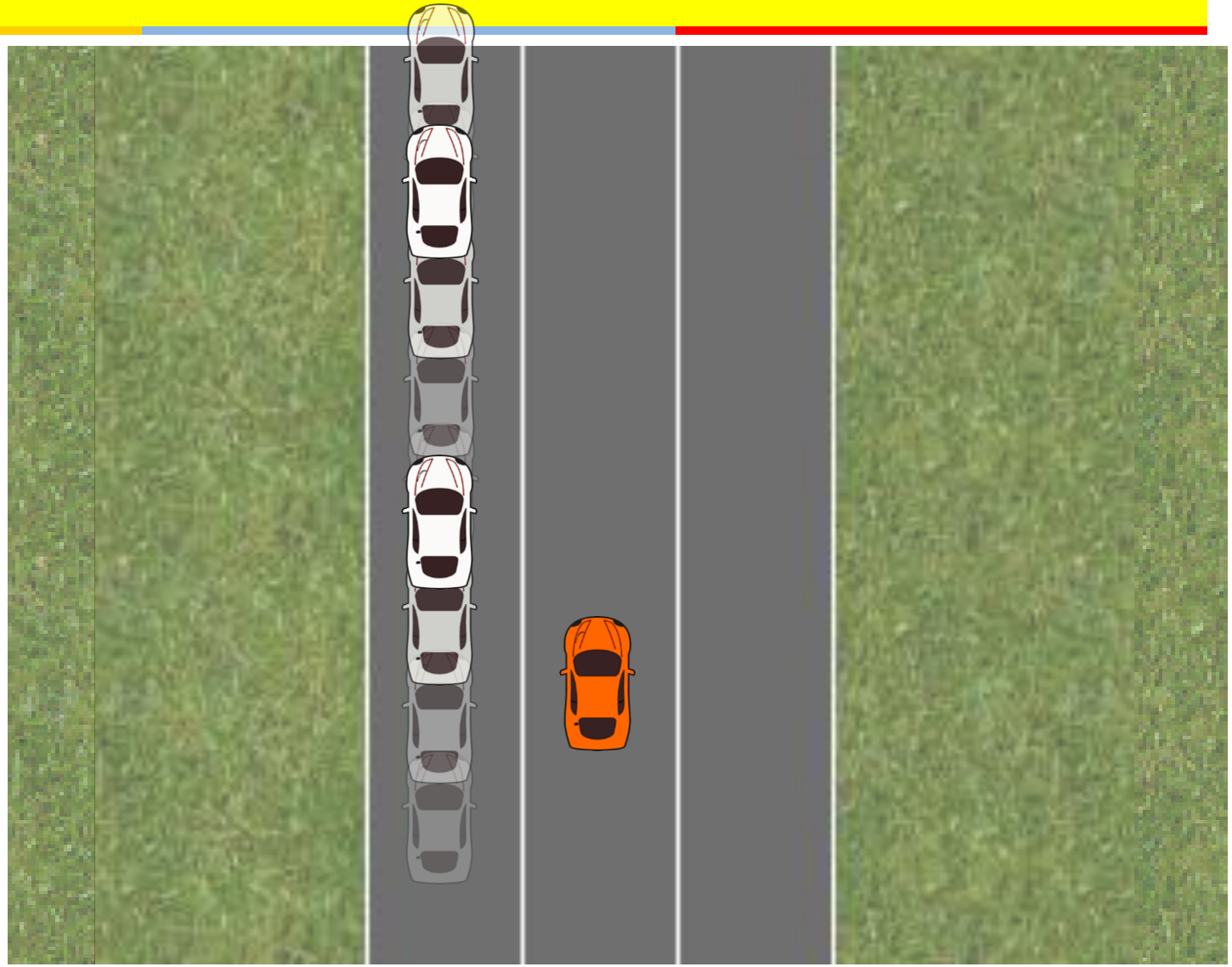


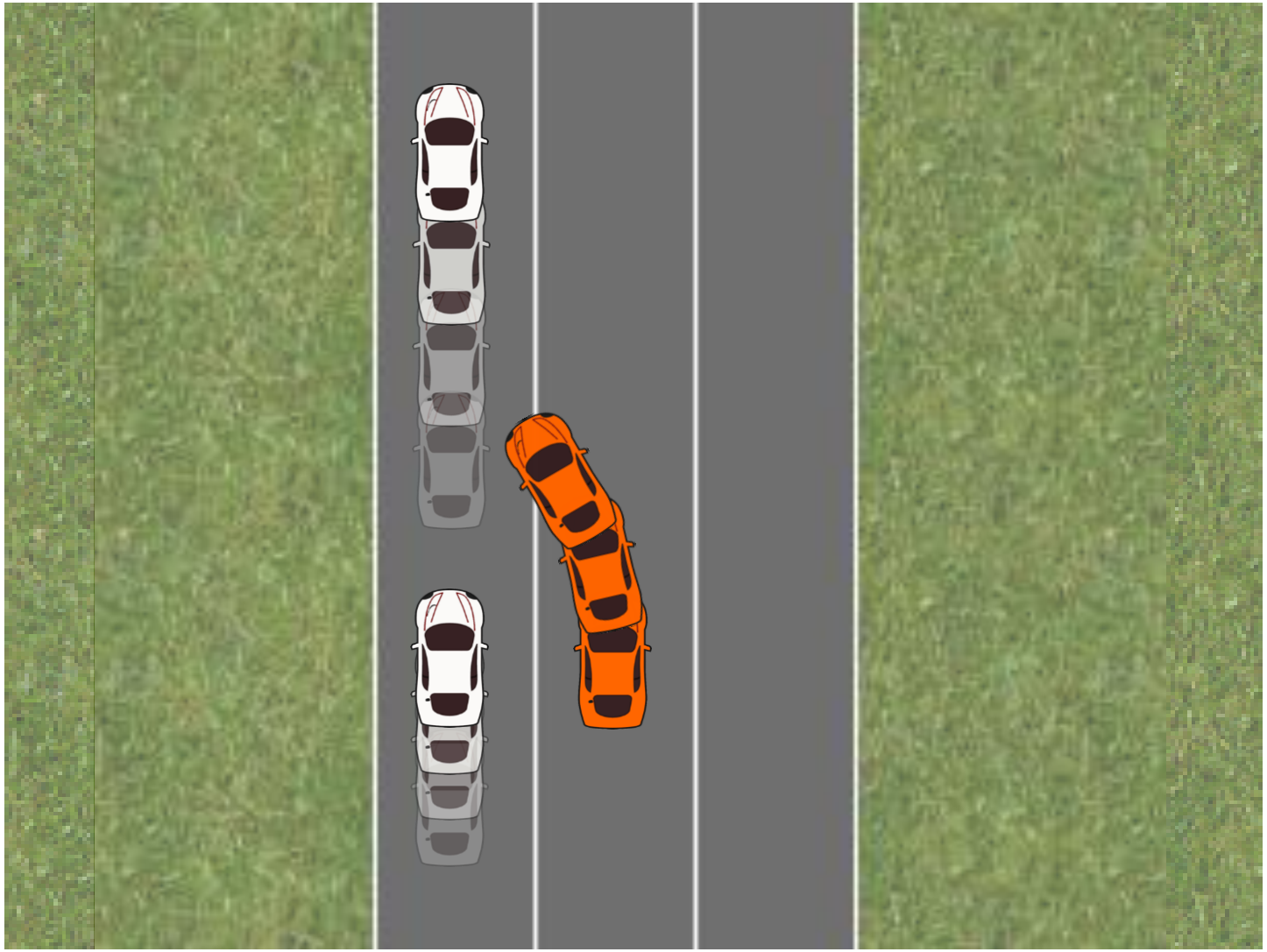
[Levine*, Finn*, Darrell, Abbeel, JMLR 2016]

Human-AI Interaction

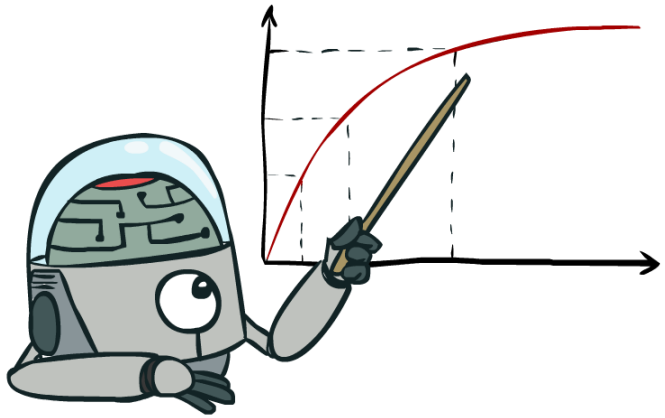








Maximize Your Expected Utility



Utility?

Clear utility function

Not so clear utility function


START
START
SCORE
0
LAPS
—/3
TIME
0:01
TURBO
MORE GAMES

Areas Contributing to AI

Philosophy
Mathematics
Economics
Neuroscience
Psychology
Computer Engineering
Control theory, Cybernetics
Linguistics

Areas Contributing to AI

Philosophy
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Linguistics

- Can formal rules be used to draw valid conclusions?
- How does the mind arise from a physical brain?
- Where does knowledge come from?
- How does knowledge lead to action?

Areas Contributing to AI

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Aristotle (384–322 B . C .) : first to formulate precise set of laws to govern rational part of brain

Ramon Lull (d. 1315) : useful reasoning could actually be carried out by a mechanical artifact

Hobbes (1588–1679) : "we add and subtract in our silent thoughts."

Leibniz (1646–1716) : Built a mechanical device intended to carry out operations on concepts rather than numbers

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Some *'isms* on the working of minds :

Rationalism - Correct Reasonings (Aristotle, Descartes …)

Dualism - A part of the human mind (or soul or spirit) that is outside of nature

Materialism - Alternative to dualism - holds that the brain's operation according to the laws of physics constitutes the mind

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Obtaining Knowledge

David Hume's (1711–1776) : First principles of induction

Logical positivism- Rudolf Carnap : Every knowledge obtained has a logical connection

Carnap (1905–1997) : A book "*The Logical Structure of the World*" (1928) defined an explicit computational procedure for extracting knowledge from elementary experiences

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Connection between knowledge and action:

Aristotle - (in *De Motu Animalium*) that actions are justified by a logical connection between goals and knowledge of the action's outcome

I need covering;
a cloak is a covering.
I need a cloak.
What I need, I have to make;
I need a cloak.
I have to make a cloak.
And the conclusion, "***I have to make a cloak***" is an action

Areas Contributing to AI

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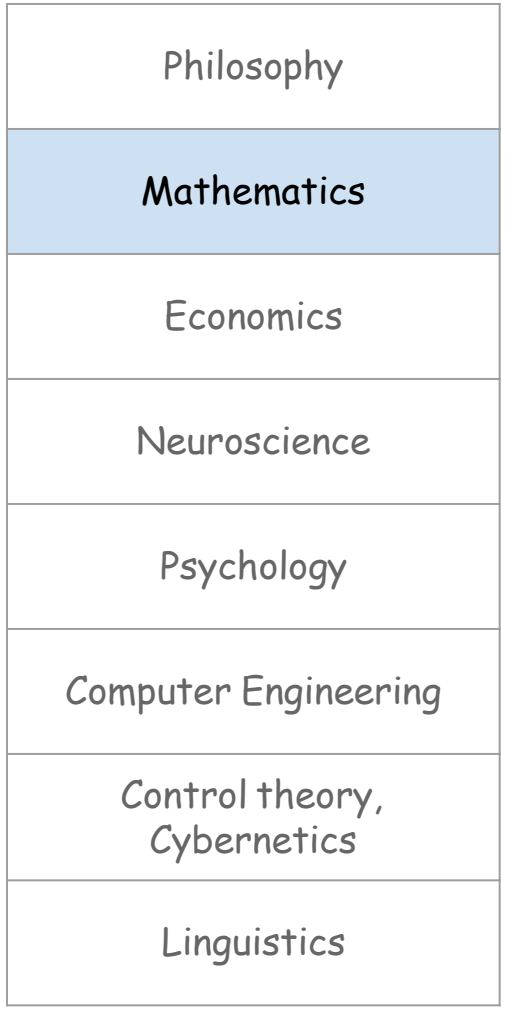
- What are the formal rules to draw valid conclusions?
- What can be computed?
- How do we reason with uncertain information?

Areas Contributing to AI

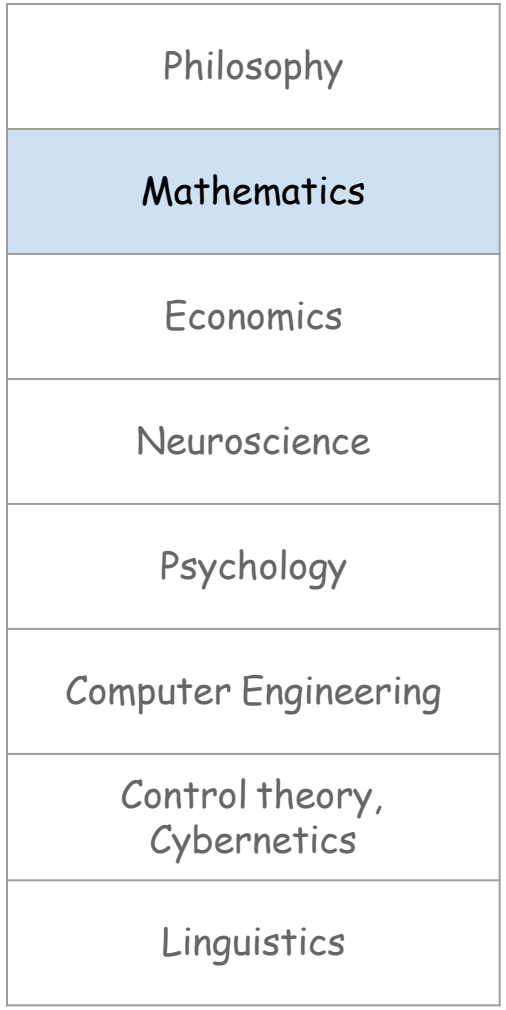


- What are the formal rules to draw valid conclusions?

George Boole (1815–1864) : Propositional Logic

Gottlob Frege (1848–1925): First order logic

Areas Contributing to AI



- What can be computed?

Kurt Gödel (1906–1978) : In any formal theory as strong as Peano arithmetic #(the elementary theory of natural numbers), there are true statements that are undecidable in the sense that they have no proof within the theory

Computability, tractability, NP-completeness

Probability theory & inference mechanisms

- https://en.wikipedia.org/wiki/Peano_axioms

Areas Contributing to AI

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- How should we make decisions so as to maximize payoff?

Utility / preferred outcomes

Decision theory -Probability & utility theory

Game theory

- How to make decisions when payoffs are not immediate?
  - MDP

Areas Contributing to AI

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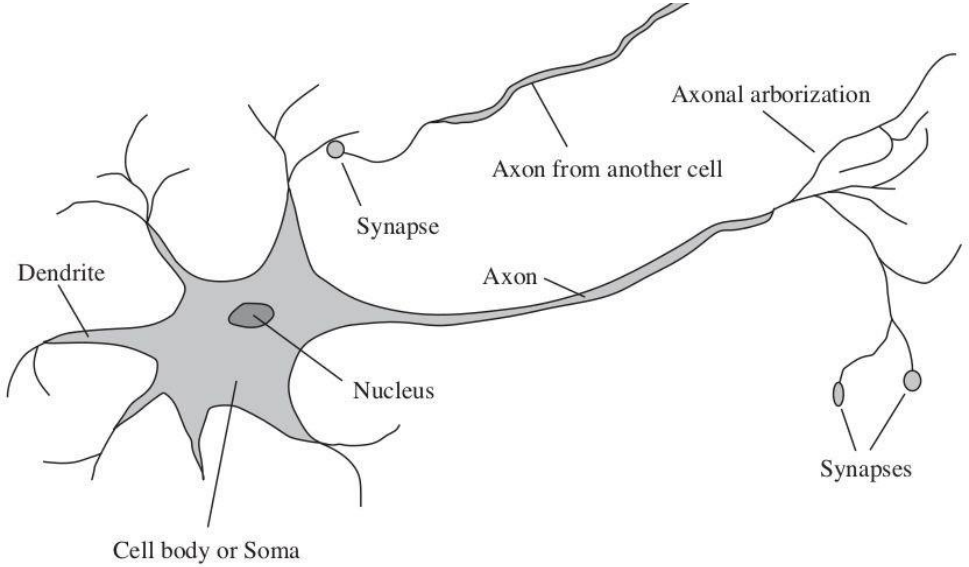
How do brains process information?

- Study of the nervous system / brain
- How does brain enables thoughts - Mystery Still

Aristotle , "*Of all the animals, man has the largest brain in proportion to his size*"



Areas Contributing to AI

- Philosophy
- Mathematics
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- **Neuroscience**
- Psychology
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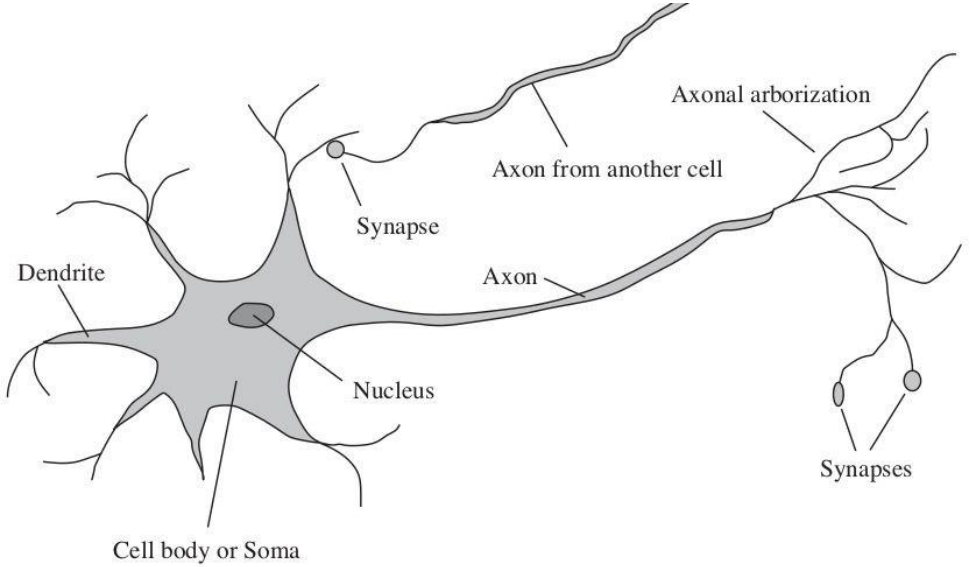
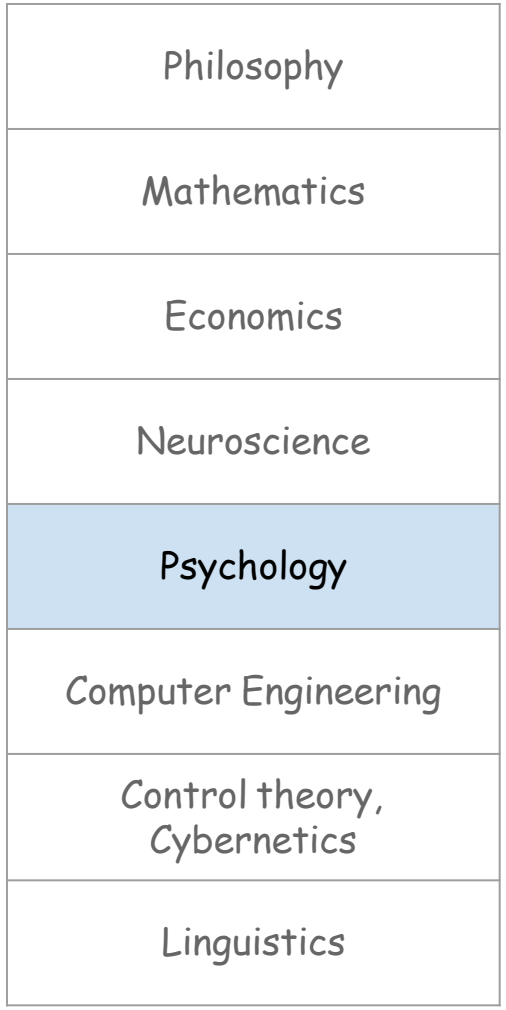
- Linguistics

	Supercomputer	Personal Computer	Human Brain
Computational units	10^4 CPUs, 10^{12} transistors	4 CPUs, 10^9 transistors	10^{11} neurons
Storage units	10^{14} bits RAM	10^{11} bits RAM	10^{11} neurons
	10^{15} bits disk	10^{13} bits disk	10^{14} synapses
Cycle time	10^{-9} sec	10^{-9} sec	10^{-3} sec
Operations/sec	10^{15}	10^{10}	10^{17}
Memory updates/sec	10^{14}	10^{10}	10^{14}



Areas Contributing to AI

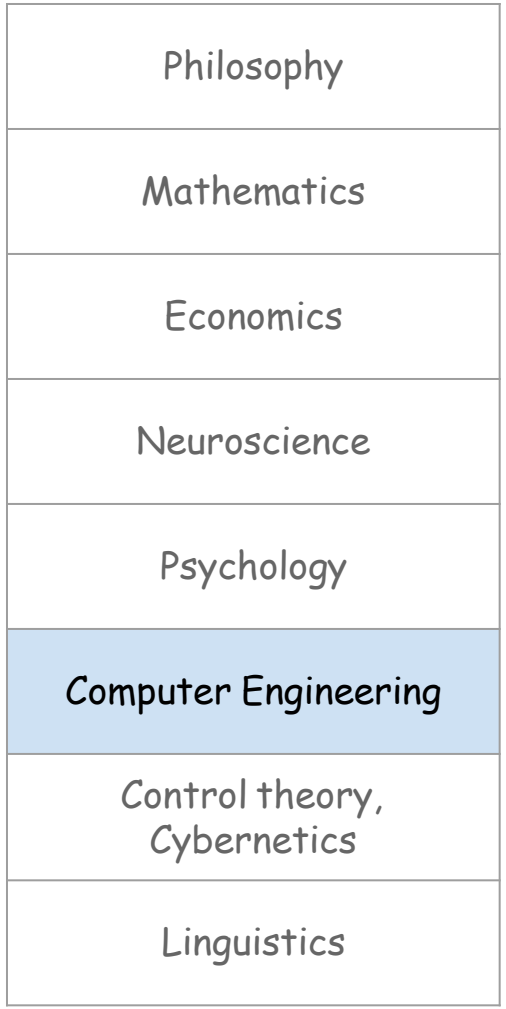


How do humans and animals think and act?

- *Cognitive Psychology* - Brain as an information-processing device
- Two months after the dartmouth workshop, a workshop in MIT gave birth to *Cognitive Science*
  - George Miller, Noam Chomsky, Allen Newell and Herbert Simon - roles of computer models to address the psychology of memory, language, and logical thinking, issues..

"*a cognitive theory should be like a computer program*" (Anderson, 1980);

Areas Contributing to AI



Computers & Programming Languages

Areas Contributing to AI

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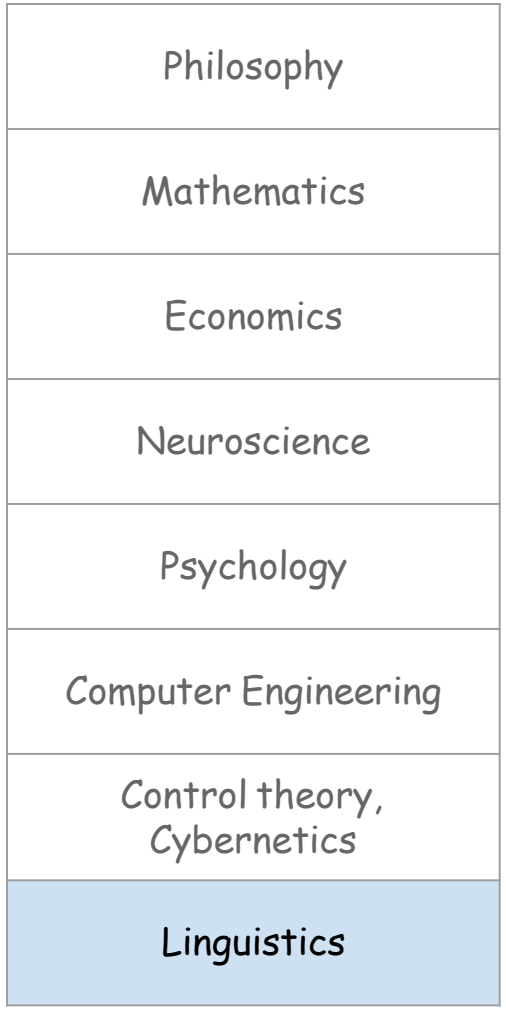
Control theory

- Deals with the behaviour of dynamic systems
  - behaviour must ensure the error between the current state and goal state is minimized
- Cybernetics - Book by Wiener
  - (Norbert Wiener, 1948) : Scientific study of control and communication in the animal and the machine
- Ashby's Design for a Brain (1948, 1952):
  - Intelligence could be created by the use of homeostatic devices containing appropriate feedback loops to achieve stable adaptive behavior
  - Led to the idea of *design of systems that maximize an objective function over time*

Areas Contributing to AI



- How does language relate to thought?
- Verbal Behavior (1957, B. F. Skinner) :
  - Behaviorist approach to language learning
  - Reviewed by Noam Chomsky
    - criticised lack of notion of creativity in language
- Syntactic Structures (1957, Noam Chomsky)
  - Computational linguistics / natural language processing as a part of AI
    - Understanding a language is realized as more complex than ever
    - Context, subject matter knowledge
    - complicated it further
    - Representing language consumed volume of work done in NLP, in early times

Deep Learning Breakthroughs (2012 – Present)

- In 2012, deep learning beat previous benchmark in the ImageNet competition.
- In 2013, deep learning is used to understand "conceptual meaning" of words.
- In 2014, similar breakthroughs appeared in language translation.
- These have led to advancements in Web Search, Document Search, Document Summarization, and Machine Translation.

Google Translate

Modern AI (2012 – Present): Deep Learning Impact

Computer vision

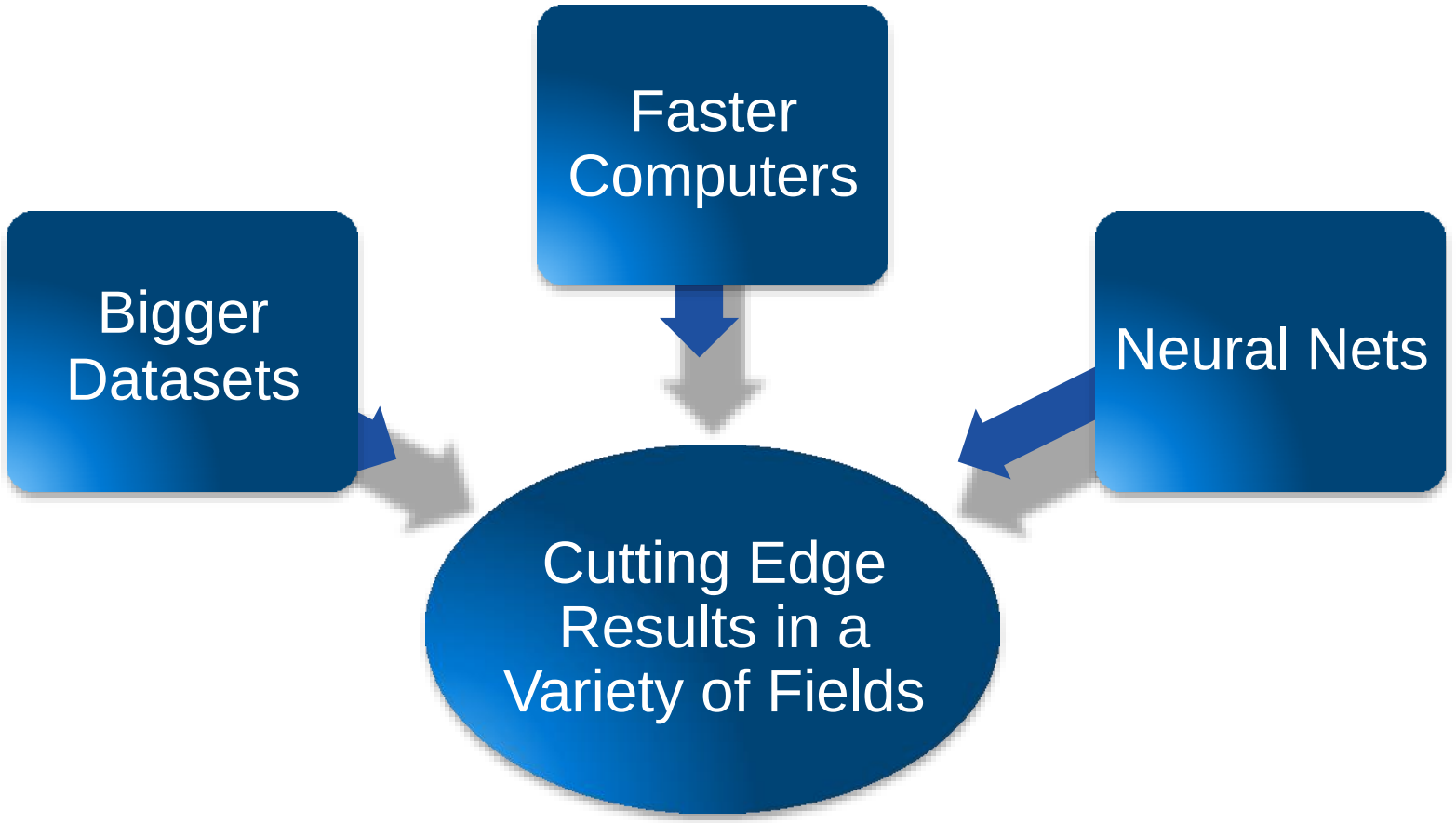
Self-driving cars:
object detection

Healthcare:
improved diagnosis

Natural language

Communication:
language translation

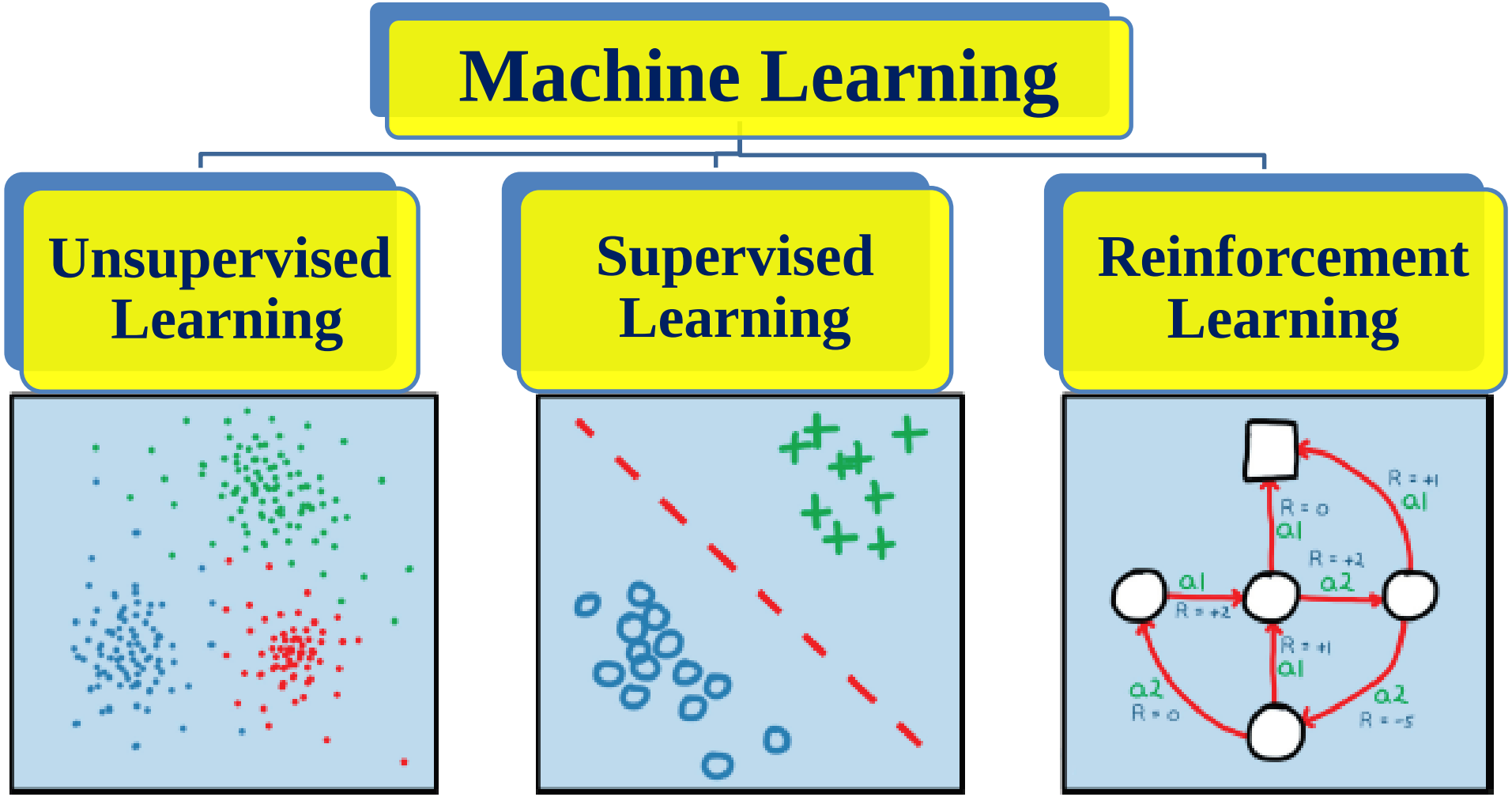
How is the AI of this Era is Different?



Other Modern AI Factors

- Continued expansion of open source AI, especially in Python*, aiding machine learning and big data ecosystems.
- Leading deep learning libraries *open-sourced*, allowing further adoption by industry.
- Open sourcing of large datasets of millions of labeled images, text datasets such as Wikipedia has also driven breakthroughs.

Three broad categories of ML



Google Data Centre Cooling

- DeepMind AI Reduces Google Data Centre Cooling Bill by 40%

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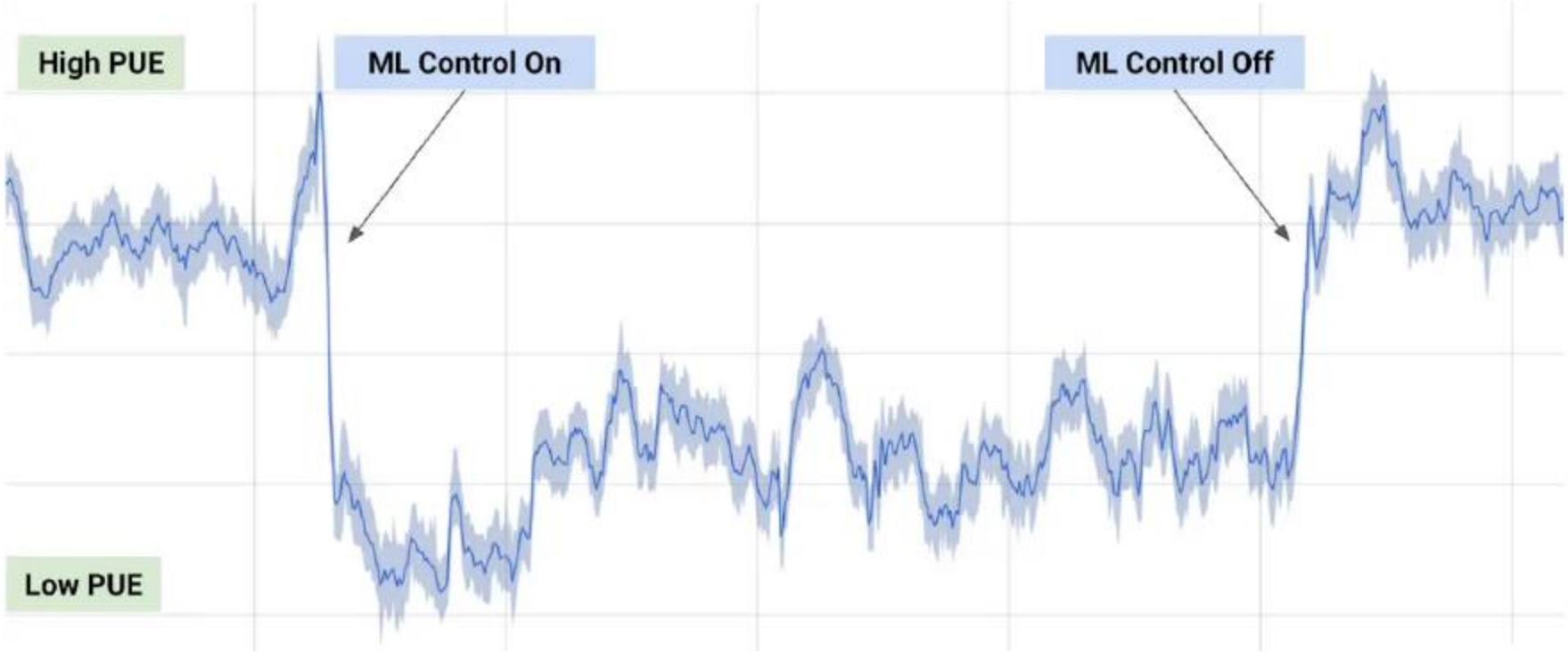

Google Data Centre Cooling

- DeepMind AI Reduces Google Data Centre Cooling Bill by 40%
- Optimal operation of pumps, chillers and cooling towers
- Compared to five years ago, Google get around 3.5 times the computing power out of the same amount of energy

The sequence episode of actions from the start to the terminal state is an episode, or a trial

Reward-free exploration An algorithm for Reward-Free Exploration (RFE) sequentially collects a database of trajectories in the following way. In each time step t, a policy $\pi^t = (\pi_h^t)_{h=1}^H$ is computed based on data from the $t-1$ previous episodes, a *reward-free episode* $z_t = (s_1^t, a_1^t, s_2^t, a_2^t, \ldots, s_H^t, a_H^t)$ is generated under the policy π^t in the MDP starting from a first state $s_1^t \sim P_0$: for all $h \in [H]$, $s_h^t \sim p_h(s_{h-1}^t, \pi^t(s_{h-1}^t)$ and the new trajectory is added to the database: $\mathcal{D}_t = \mathcal{D}_{t-1} \bigcup \{z_t\}$. At the end of each episode, the algorithm can decide to stop collecting data (we denote by τ its random stopping time) and outputs the dataset $\mathcal{D}_\tau$.

- Reference: Emilie Kaufmann et al. Adaptive Reward-Free Exploration https://arxiv.org/pdf/2006.06294.pdf

AI in Transportation

Navigation

Google & Waze find the fastest route, by processing traffic data.

Ride sharing

Uber & Lyft predict real-time demand using AI techniques, machine learning, deep learning.

AI in Social Media

Audience

Facebook & Twitter use AI to decide what content to present in their feeds to different audiences.

Content

Image recognition and sentiment analysis to ensure that content of the appropriate “mood” is being served.

Thank You

Required Reading:

AIMA - Chapter # 1.1
AIMA - Chapter # 1.2 - Must Read & Google a lot

Note : Some of the slides are adopted from Prof. Vimal archives