# AI61009
# Artificial Intelligence Foundations and Applications

Partha Pratim Chakrabarti

Plaban Bhowmik

Sudeshna Sarkar

Centre of Excellence in Artificial Intelligence

IIT Kharagpur

# Acknowledgement of sources

- Some content and slides have been borrowed from
- CS188 at UC Berkeley (Instructors: Dan Klein and Pieter Abbeel)
  - From ai.berkeley.edu
- CS221 at Stanford University
- Peter Stone and Zhu: Texas Austin

# Topics

- What is artificial intelligence?
- A brief history of AI
- AI Paradigms
- AI Techniques

# AI Applications?

- Face recognition
- Machine learning
- Robots
- Voice assistants

# AI Risks?

# What is Artificial Intelligence?

"the scientific understanding of the mechanisms underlying thought and intelligent behavior and their embodiment in machines.“

-- (AAAI)

It's the quest to build machines that can reason, learn, and act intelligently,.

…

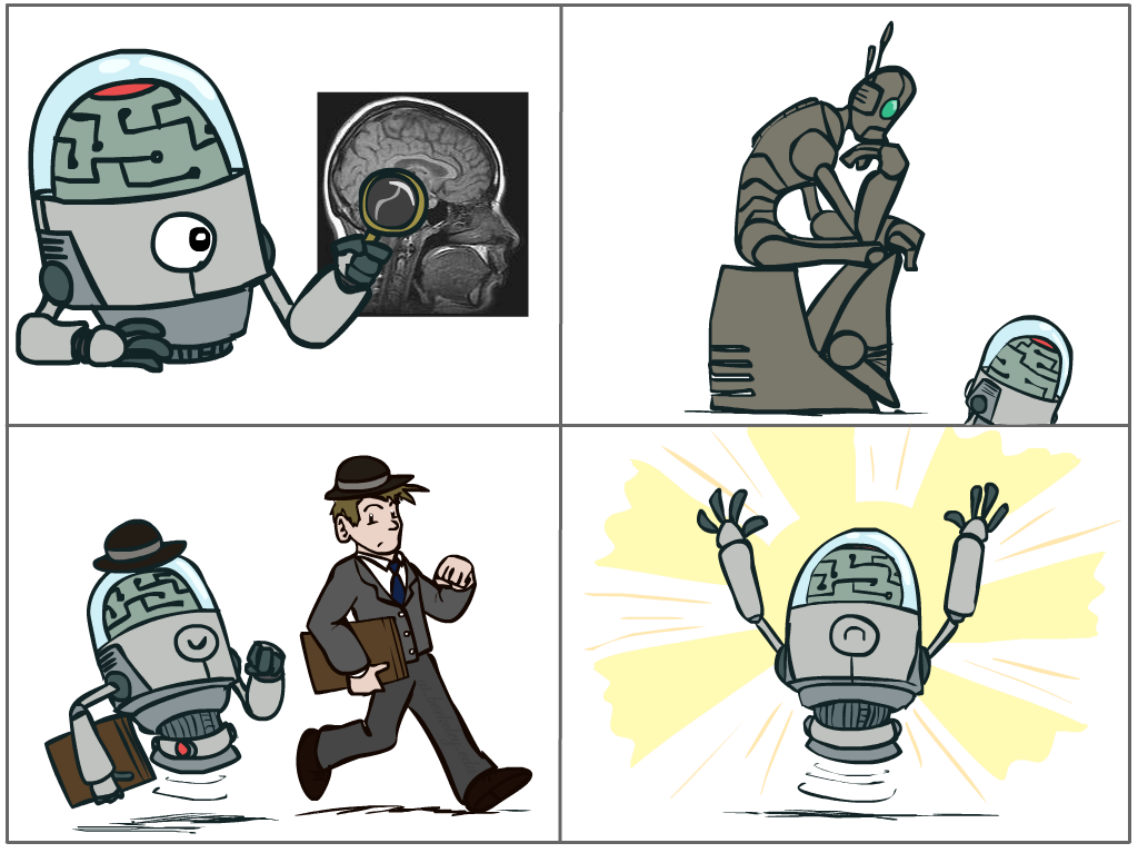
# Why AI?

- **Engineering:** To get machines to do a wider variety of useful things
  - e.g., understand spoken natural language, recognize individual people in visual scenes, find the best travel plan for your vacation, etc.
- **Cognitive Science:** As a way to understand how natural minds and mental phenomena work
  - e.g., visual perception, memory, learning, language, etc.
- **Philosophy:** As a way to explore some basic and interesting (and important) philosophical questions
  - e.g., the mind body problem, what is consciousness, etc.

# What is AI?

The science of making machines that:

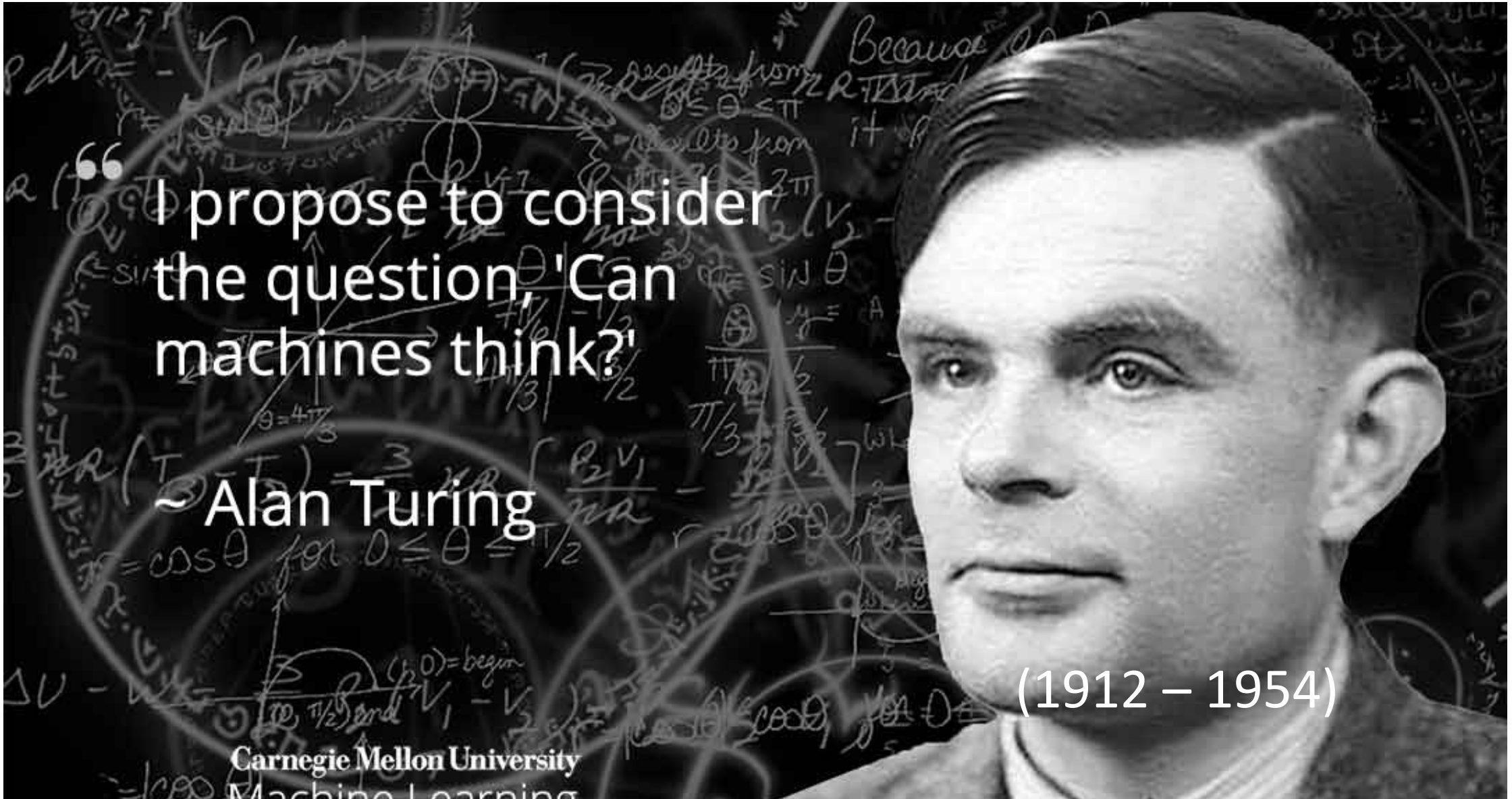
Think like people



Think rationally

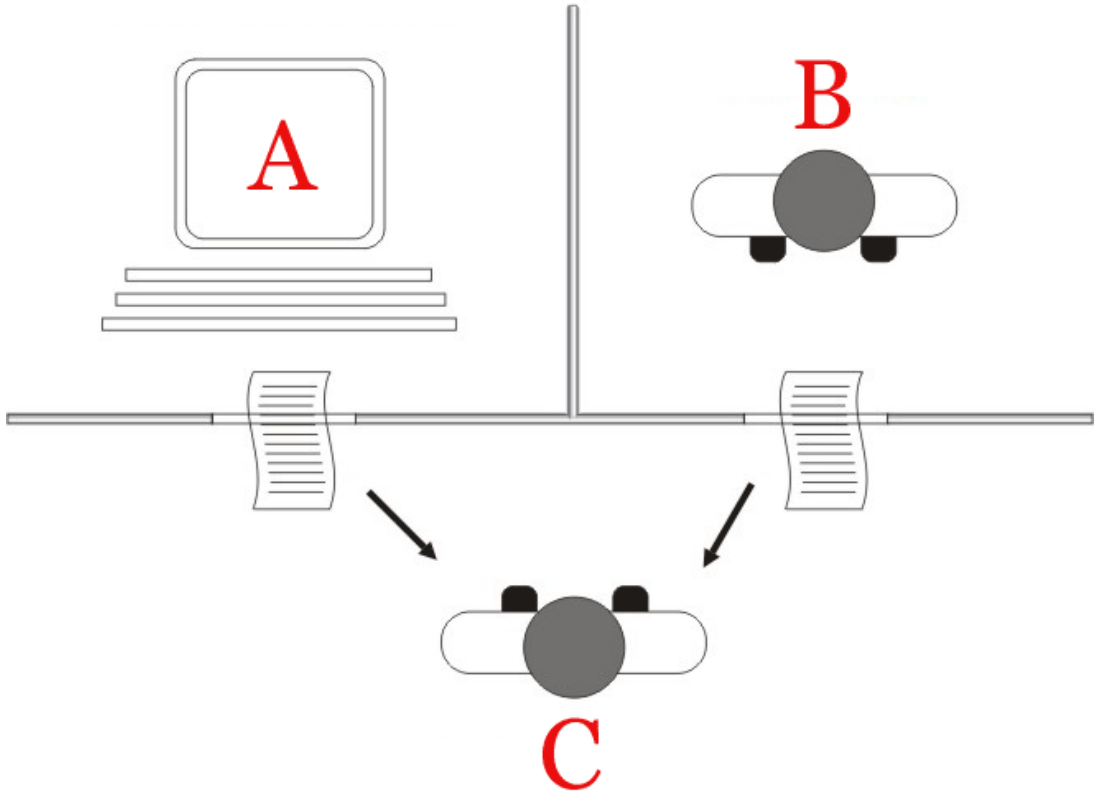
Act like people

Act rationally


“I propose to consider the question, 'Can machines think?'
~ Alan Turing
(1912 – 1954)
Carnegie Mellon University
Machine Learning

# Turing Test

"A Computer would deserve to be called intelligent if it could deceive a human into believing that it was human"




en.wikipedia.org/wiki/Turing_test

# The Birth of AI

# 1956 Dartmouth Conference: The Founding Fathers of AI


John MacCarthy


Marvin Minsky

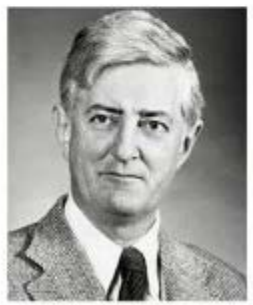

Claude Shannon


Ray Solomonoff


Alan Newell


Herbert Simon


Arthur Samuel


Oliver Selfridge


Nathaniel Rochester


Trenchard More

**"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."**

A Proposal for the

DARTMOUTH SUMMER RESEARCH PROJECT ON ARTIFICIAL INTELLIGENCE

June 17 - Aug. 16

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.

The following are some aspects of the artificial intelligence problem:

1) Automatic Computers

If a machine can do a job, then an automatic calculator can be programmed to simulate the machine. The speeds and memory capacities of present computers may be insufficient to simulate many of the higher functions of the human brain, but the major obstacle is not lack of machine capacity, but our inability to write programs taking full advantage of what we have.

2) How Can a Computer be Programmed to Use a Language

It may be speculated that a large part of human thought consists of manipulating words according to rules of reasoning

Photo courtesy Dartmouth College.

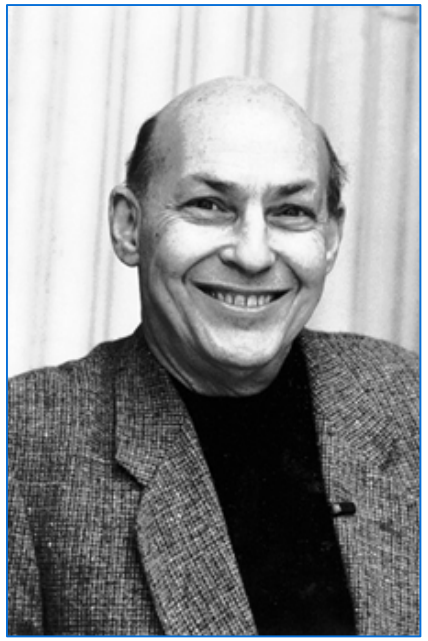
*Page 1 of the Original Proposal.*

*"machines will be capable, within twenty years, of doing any work a man can do."*

Herbert Simon (1965)

*"In from three to eight years we will have a machine with the general intelligence of an average human being."*

Marvin Minsky (1970)

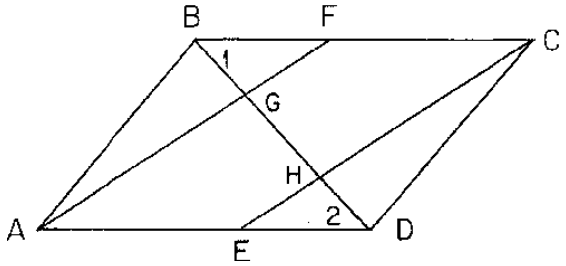


# Early Successes

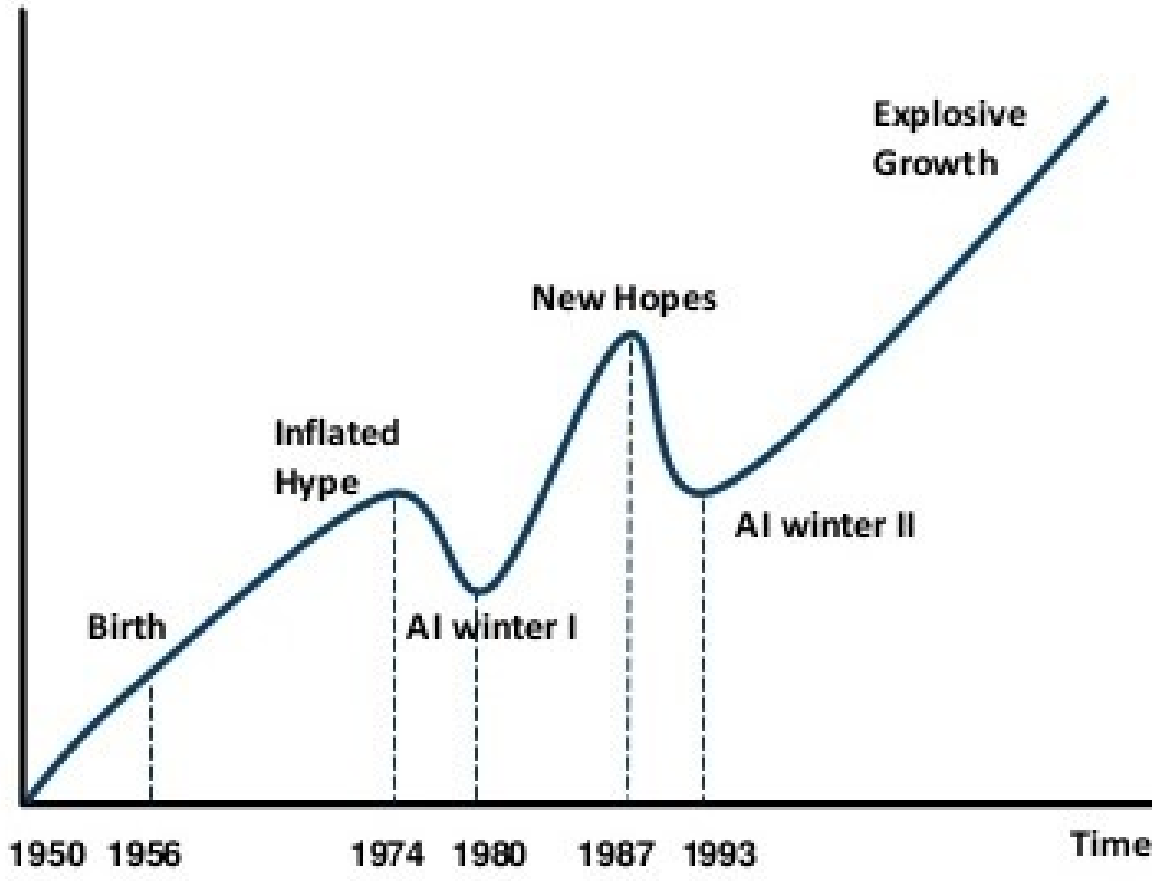
- Checker playing program
  (Arthur Samuel, 1952)

- Logic Theorist (1955) Newell and Simon
- General Problem Solver (1960)

- Geometry Engine



# AI Hype and Progress Timelines




Actuaries Digitals: The History of AI Winters

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
- First Neural Networks and Perceptrons written
- First Machine Translation

# Disappointing performance

The spirit is willing but the flesh is weak.


The vodka is good but the meat is rotten.

Problems:

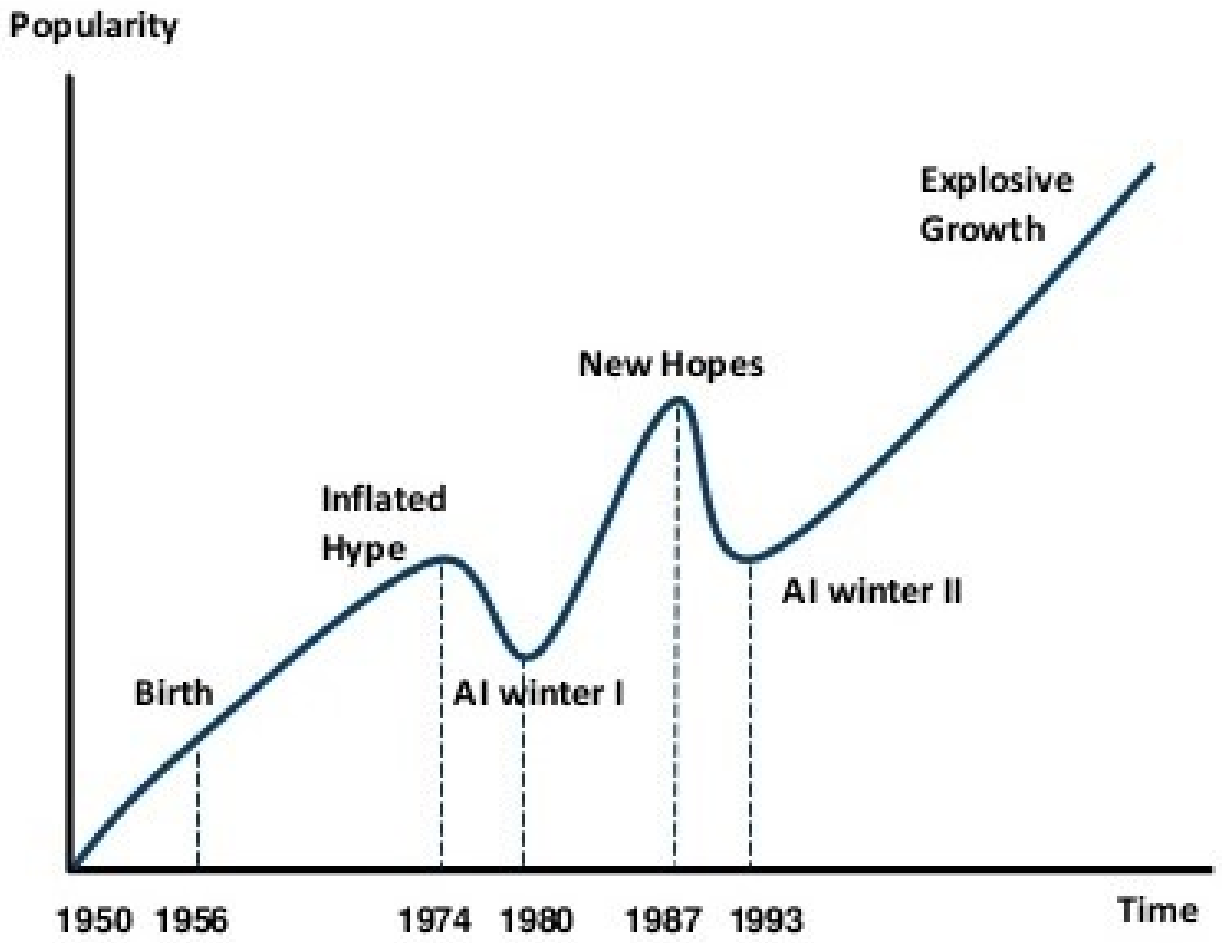
Limited computation

Search space grew exponentially

Limited information: complexity of AI problems (number of words, objects, concepts in the world)

1966: ALPAC report cut off government funding for MT, first AI winter

# First AI Winter

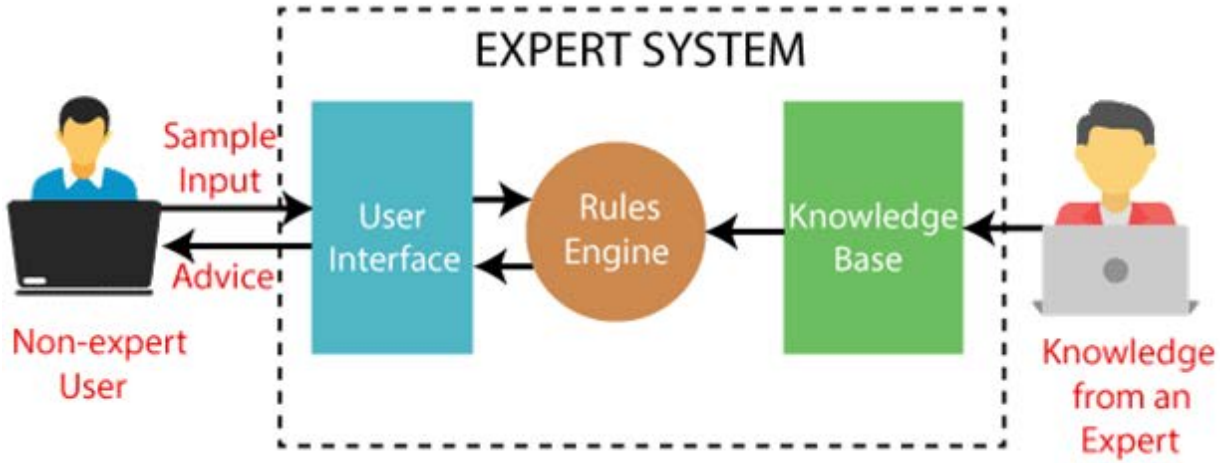



1969: Minsky & Papert published *Perceptrons* pointing out the limitations of single layer perceptrons.

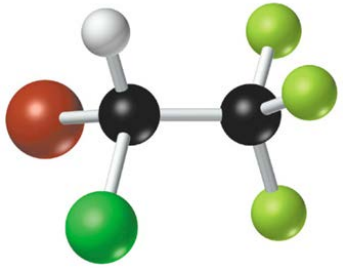
1974: Lighthill report
"in no part of the field have the discoveries made so far produced the major impact that was promised."

*The hard problems are easy, and the easy problems are hard.*

# Knowledge-based systems (70-80s)



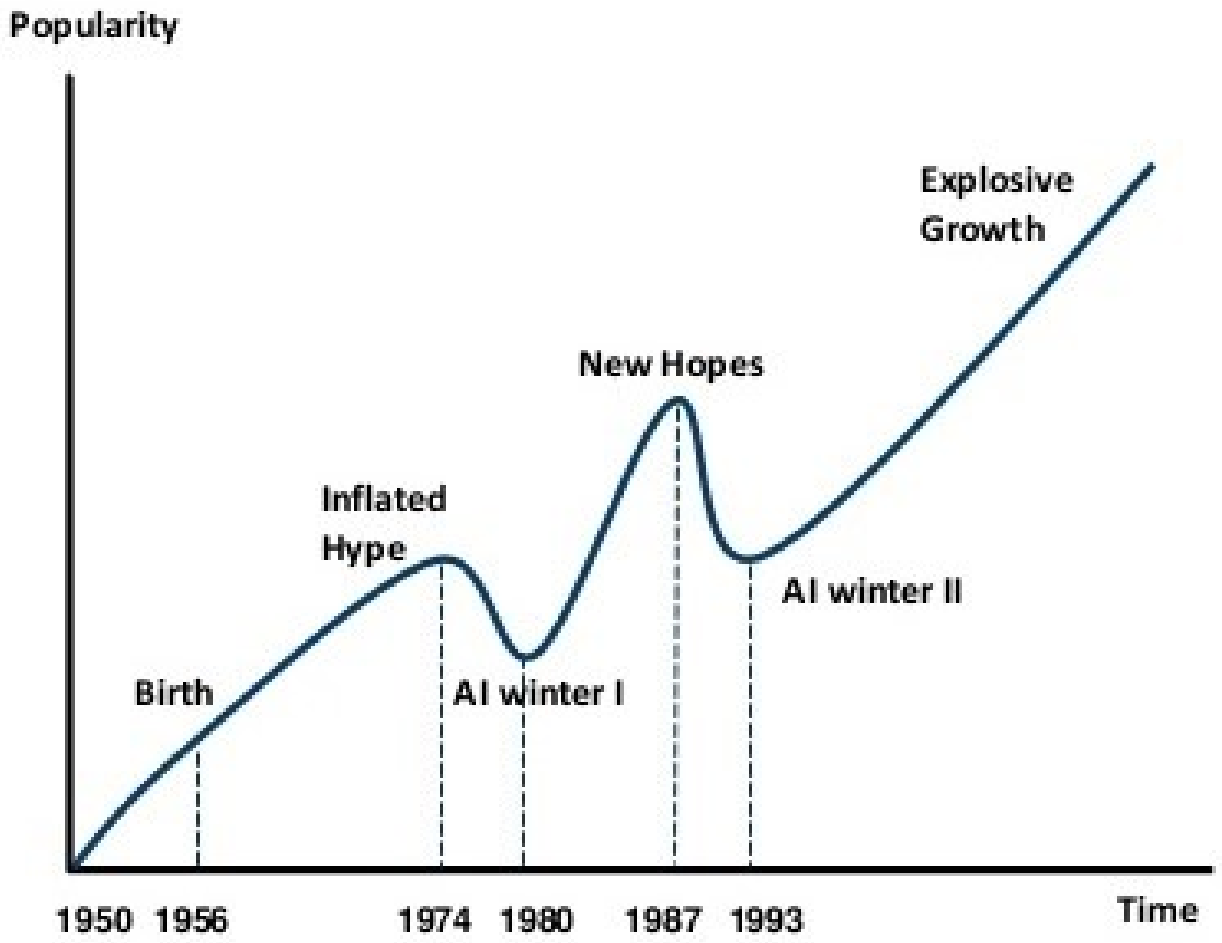

DENDRAL: infer molecular structure from mass spectrometry



MYCIN: diagnose blood infections, recommend antibiotics

XCON: convert customer orders into parts specification

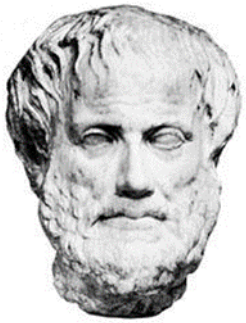
# AI Timeline




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”

# Three Paradigms of AI

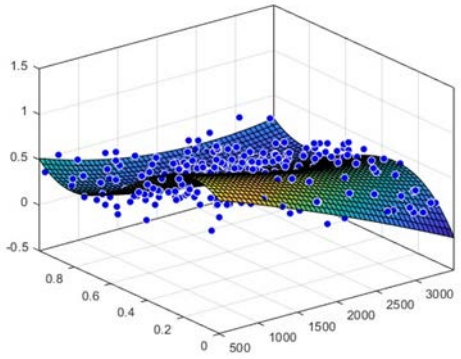


Symbolic

Paradigms of AI

Statistical

Neural




# Artificial neural networks

- 1943: artificial neural networks, relate neural circuitry and mathematical logic (McCulloch/Pitts)

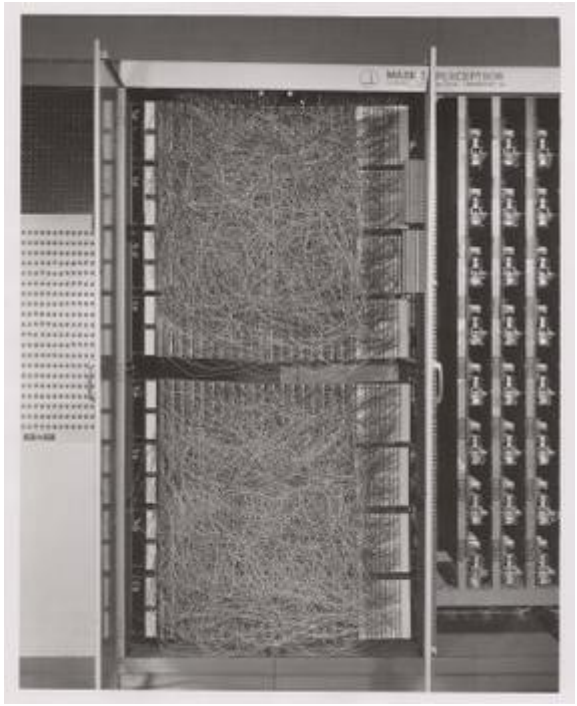
- 1949: “*cells that fire together wire together*” learning rule (Hebb)

# Rosenblatt and Perceptron

1958: Frank Rosenblatt created the perceptron learning algorithm, the simplest type of neural network with only one layer of neurons connecting inputs to outputs.

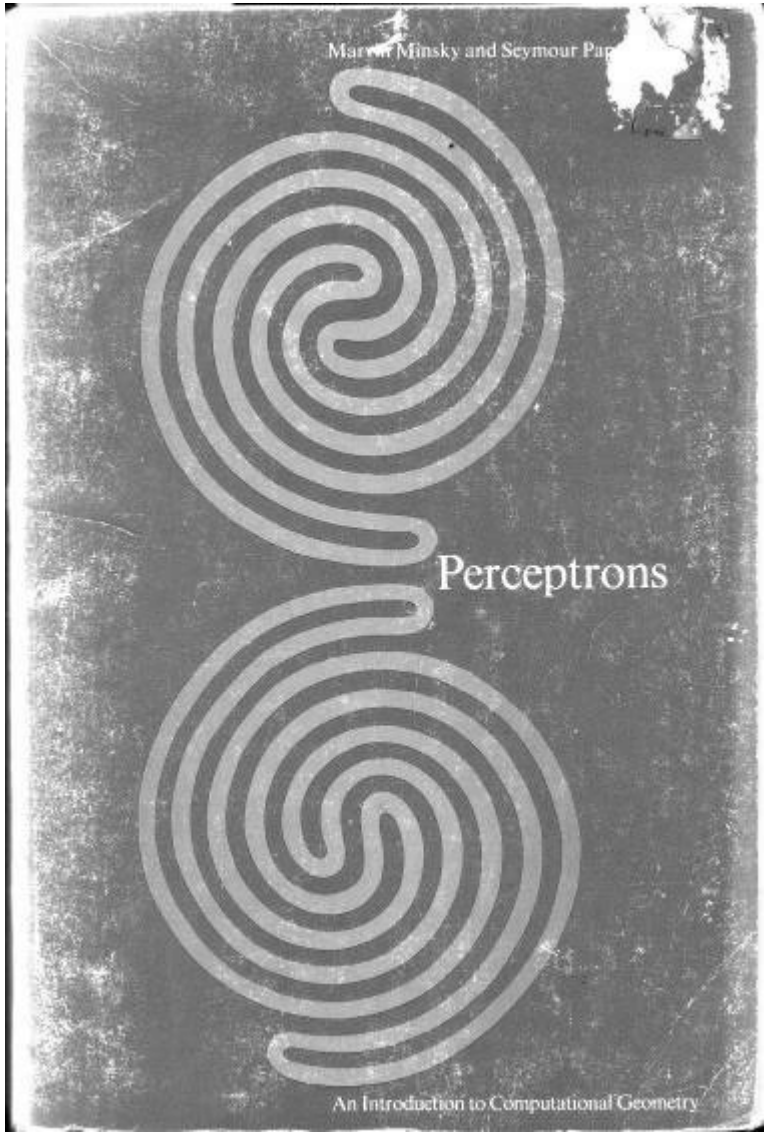
The New York Times sensationally reported the perceptron to be

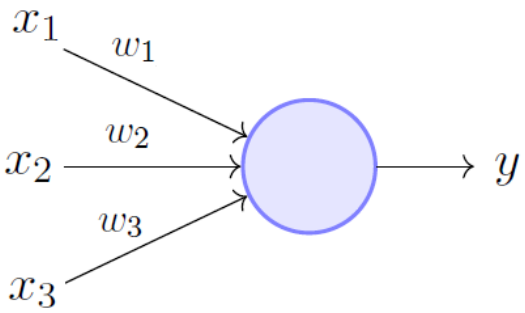
"the embryo of an electronic computer that the Navy expects will be able to walk, talk, see, write, reproduce itself and be conscious of its existence."

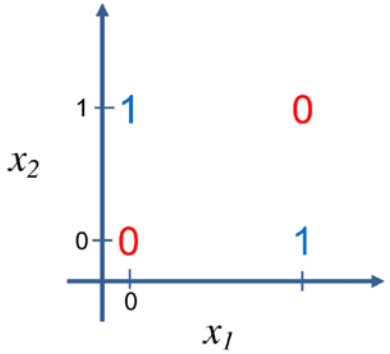


First implementation of the perceptron in the Mark 1 perceptron machine that could recognize images with a 20x20 pixel camera

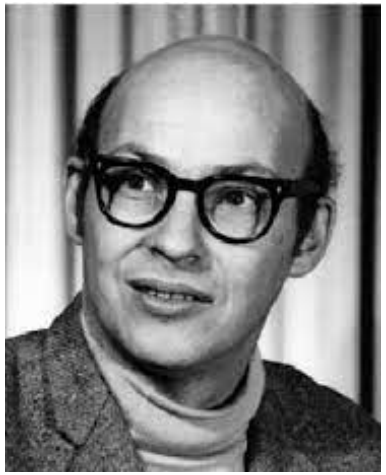
# 1969: Perceptrons

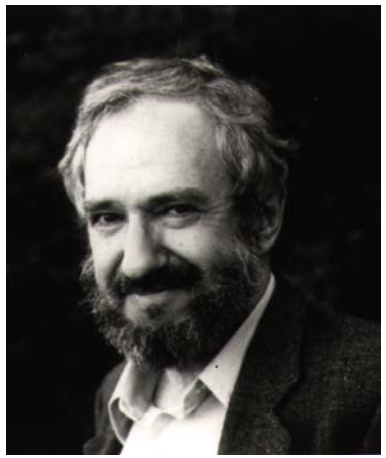



Perceptron Model (Minsky-Papert in 1969)

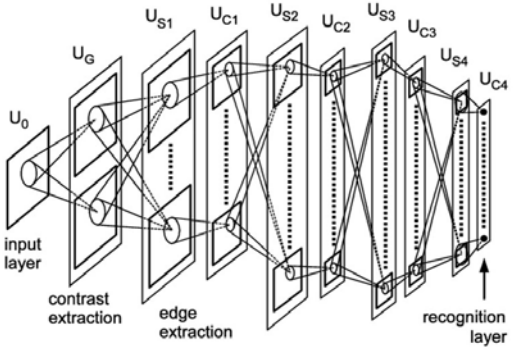




Perceptrons book showed that linear models could not solve XOR, killed neural nets research

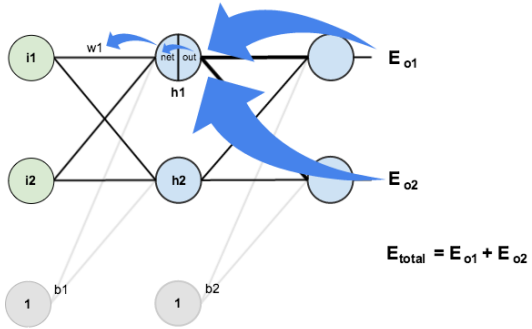
# Revival of connectionism

- 1980: Neocognitron, a.k.a. convolutional neural networks for images (Fukushima)
- 1986: popularization of backpropagation for training multi-layer networks (Rumelhardt, Hinton, Williams)
- 1989: applied convolutional neural networks to recognizing handwritten digits for USPS (LeCun)

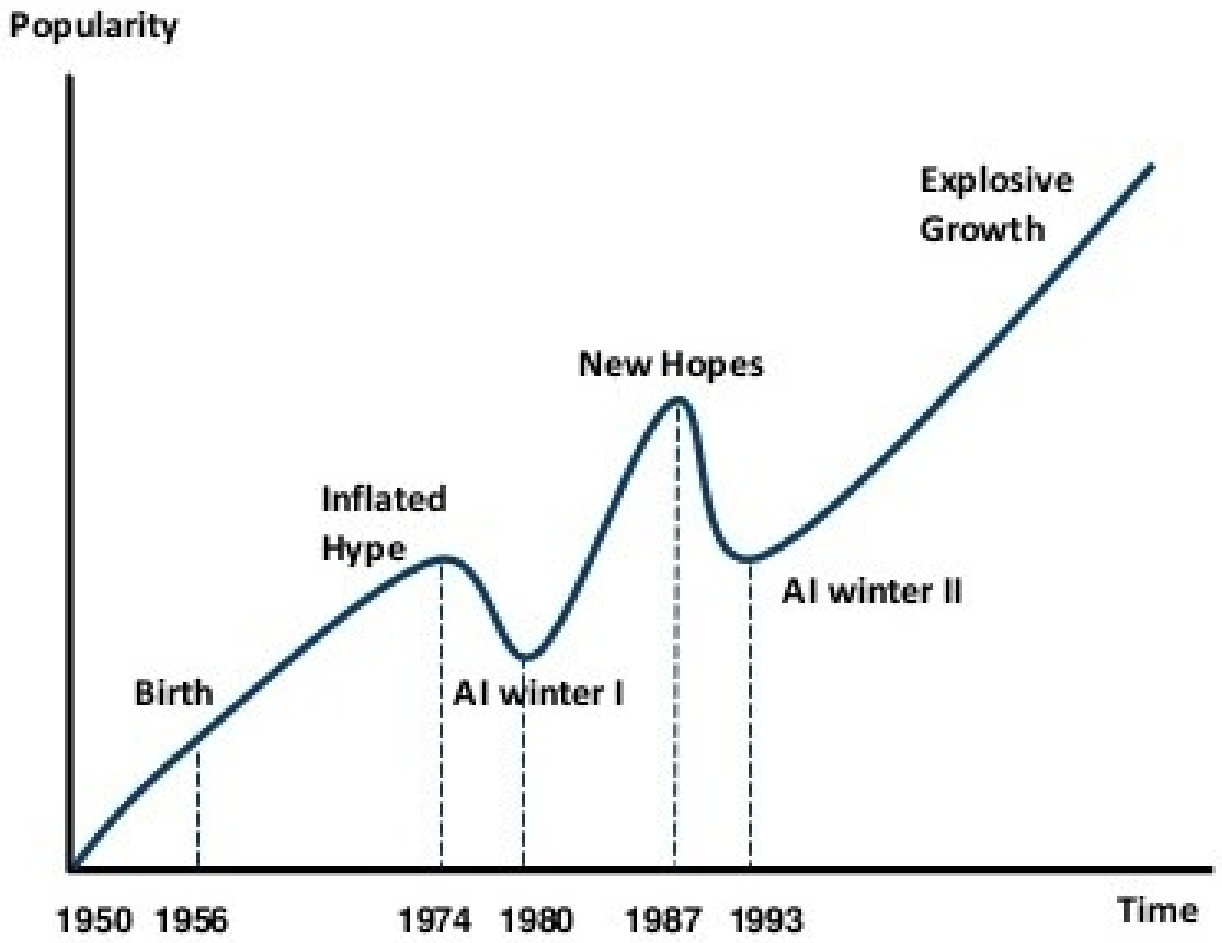



$$\frac{\partial E_{total}}{\partial w_1} = \frac{\partial E_{total}}{\partial out_{h1}} * \frac{\partial out_{h1}}{\partial net_{h1}} * \frac{\partial net_{h1}}{\partial w_1}$$

$$\frac{\partial E_{total}}{\partial out_{h1}} = \frac{\partial E_{o1}}{\partial out_{h1}} + \frac{\partial E_{o2}}{\partial out_{h1}}$$




# AI Timeline




1990—: Statistical approaches

- Resurgence of probability, focus on uncertainty
- General increase in technical depth
- Agents and learning systems… “AI Spring”?

# Deep learning

- 2006: unsupervised layerwise pre-training of deep networks (Hinton et al.)
- 2012: AlexNet obtains huge gains in object recognition; transformed computer vision community overnight
- 2016: AlphaGo uses deep reinforcement learning, defeat world champion Lee Sedol in Go

# Early ideas

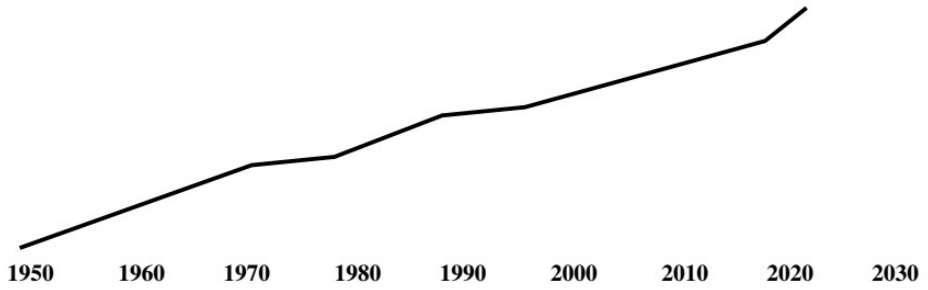
- 1801: linear regression (Gauss, Legendre)
- 1936: linear classification (Fisher)
- 1956: Uniform cost search for shortest paths (Dijkstra)
- 1957: Markov decision processes (Bellman)

# Statistical Machine Learning

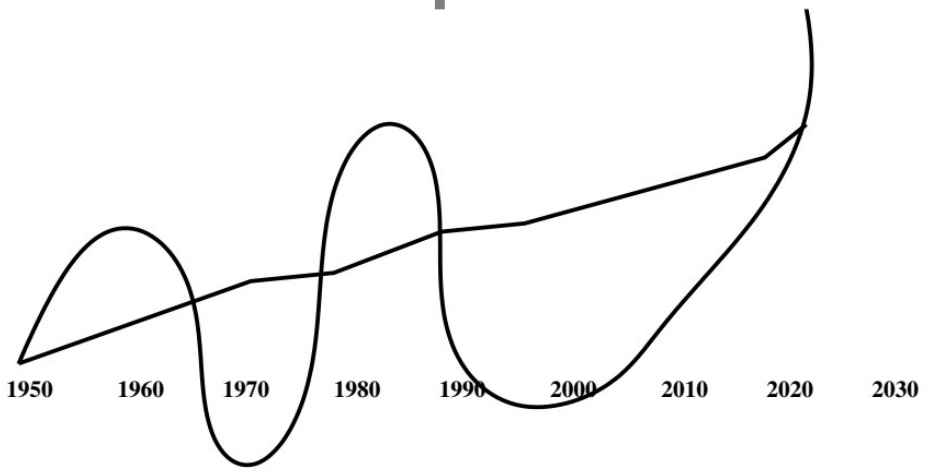
- 1985: Bayesian networks (Pearl)
- 1995: Support vector machines (Cortes/Vapnik)

# AI Hype

**Reality**




**Perceptions**




Peter Stone and Yuke Zhu, Texas Austin

# Rational Decisions

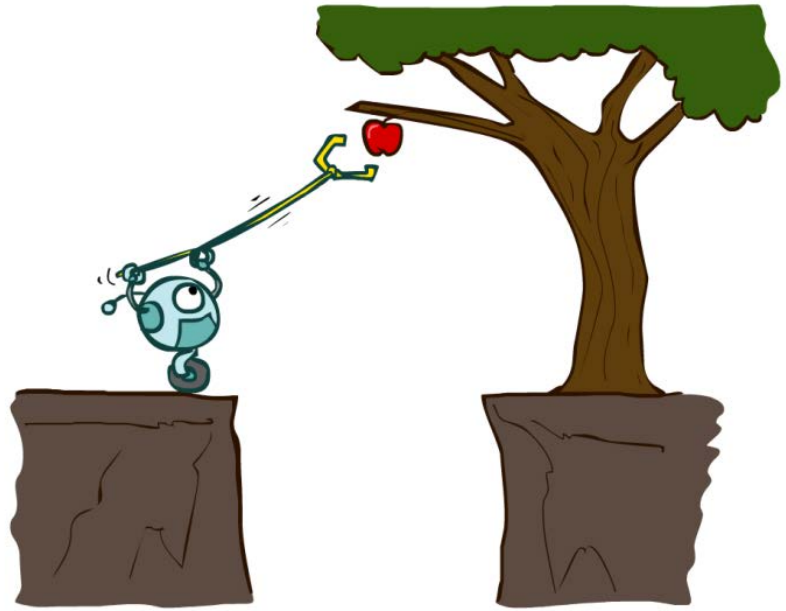
The term **rational** :

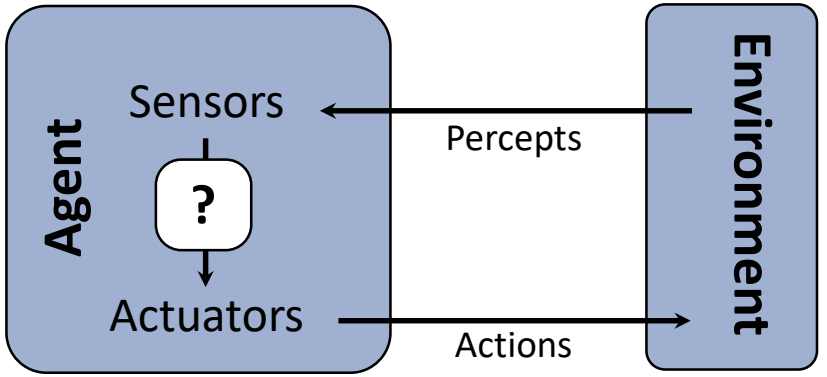
- Rational: maximally achieving pre-defined goals
- Rationality only concerns what decisions are made
  (not the thought process behind them)
- Goals are expressed in terms of the **utility** of outcomes
- Being rational means **maximizing your expected utility**

# Designing Rational Agents

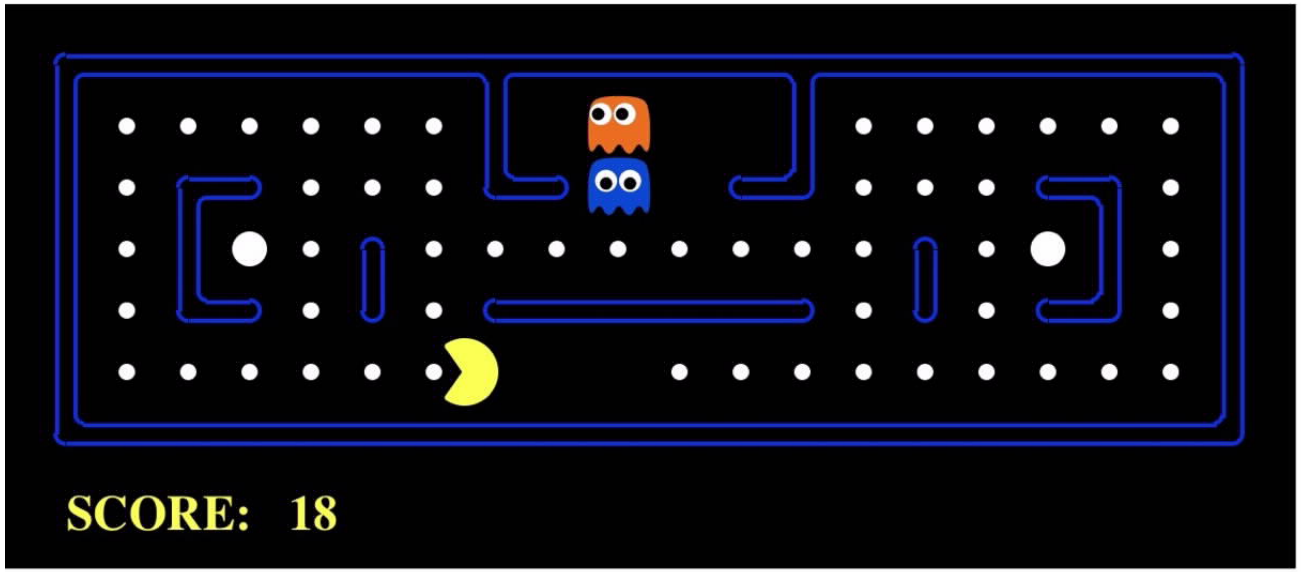
An **agent** is an entity that *perceives* and *acts*.

- What is rational depends on:
  - Performance measure
  - Agent's prior knowledge of environment
  - Actions available to agent
  - Percept sequence to date





# 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**: North, South, East, West, (Stop)

**Sensors**: Entire state is visible

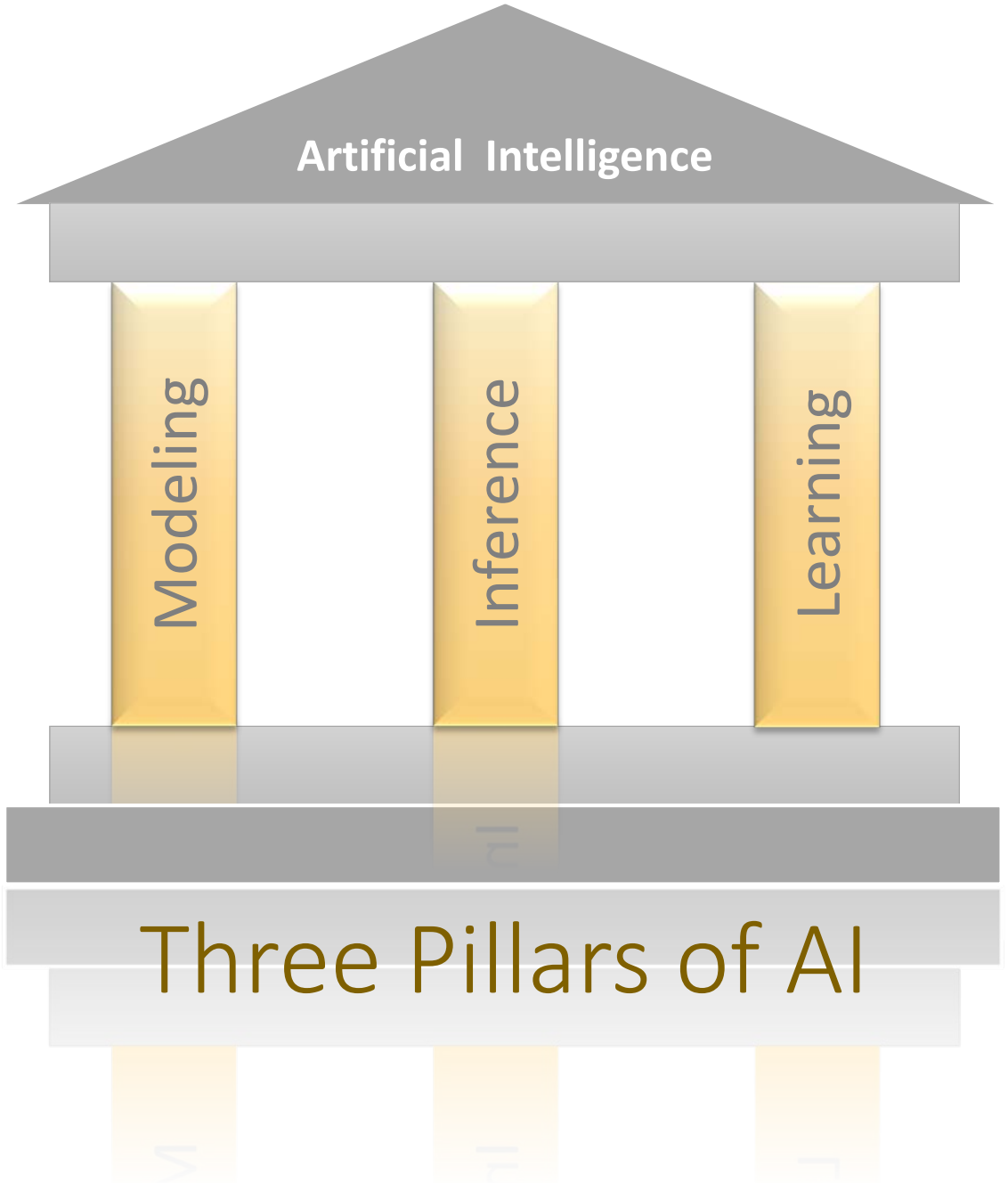
# PEAS: Automated Taxi

- Performance measure: Income, happy customer, vehicle costs, fines, insurance premiums
- Environment: City streets, other drivers, customers
- Actuators: steering, brake, fuel,
- Sensors: Camera, radar, accelerometer, engine sensors, microphone

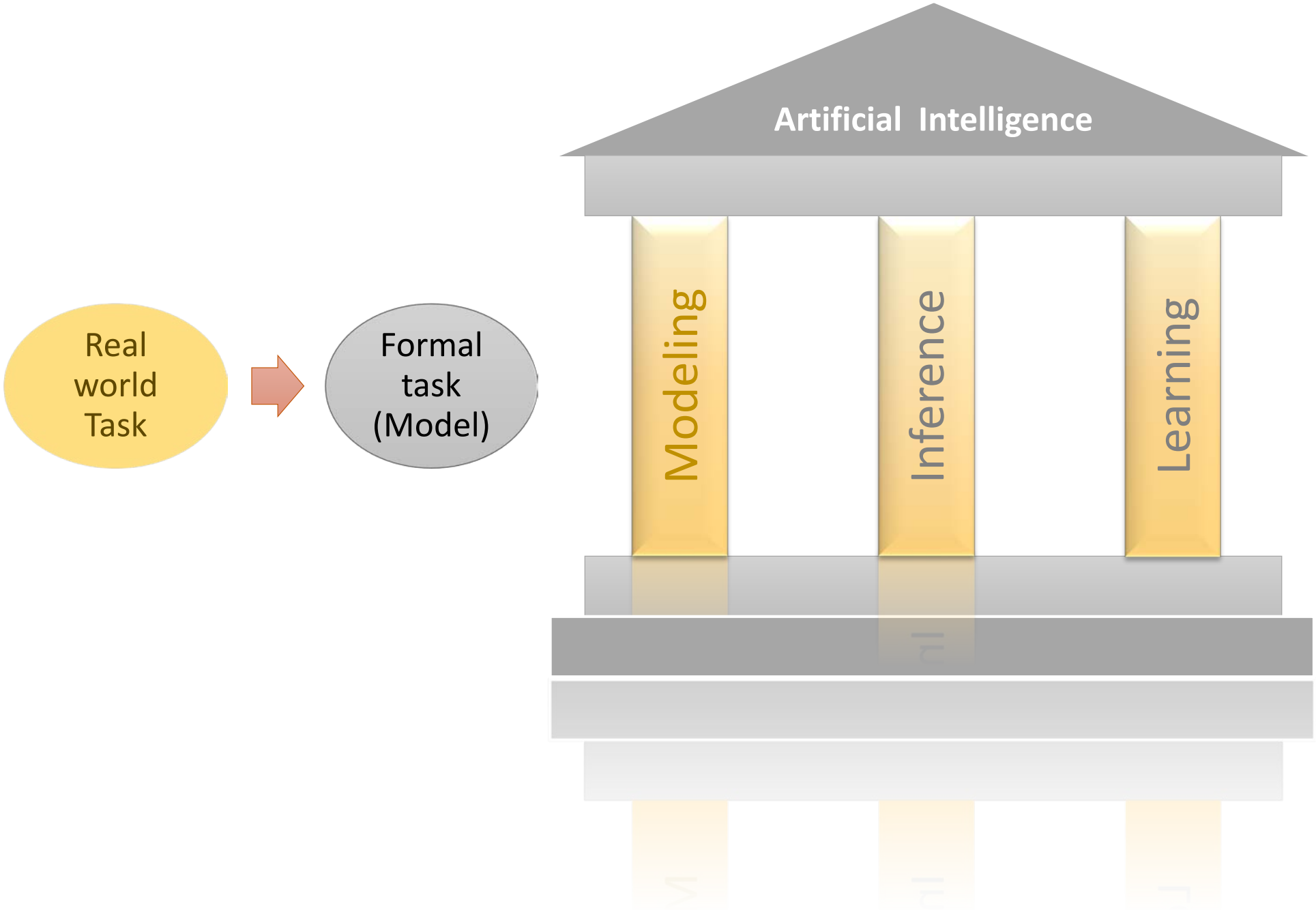
Image: http://nypost.com/2014/06/21/how-google-might-put-taxi-drivers-out-of-business/

# Environment Types

| | Pacman | Taxi |
|---|---|---|
| Fully or partially observable | | |
| Single agent or multi-agent | | |
| Deterministic or stochastic | | |
| Static or dynamic | | |
| Discrete or continuous | | |



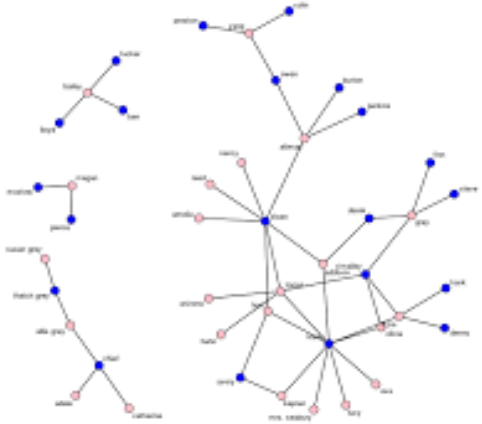

# Three Pillars of AI


Real world Task
Formal task (Model)
Artificial Intelligence
Modeling
Inference
Learning

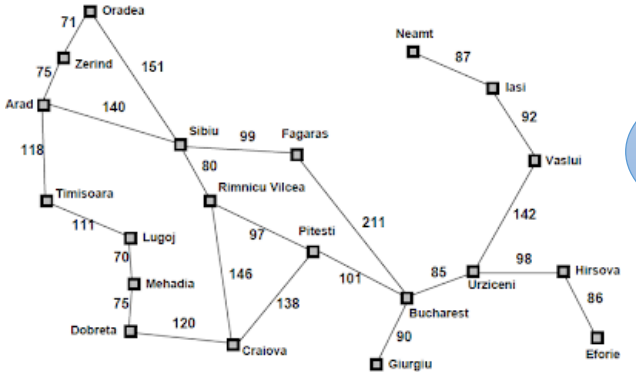
# Modeling

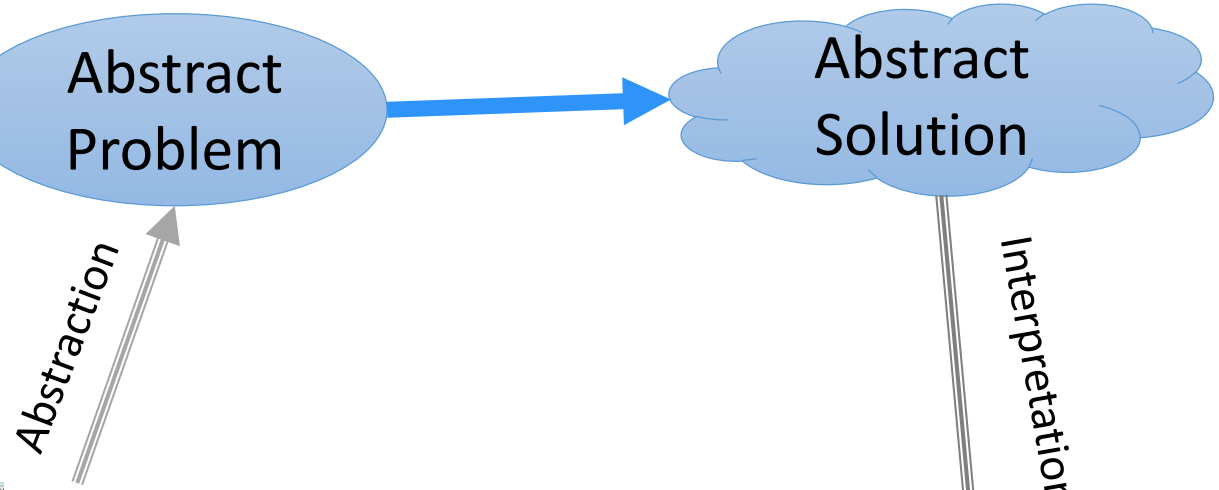
## Real World

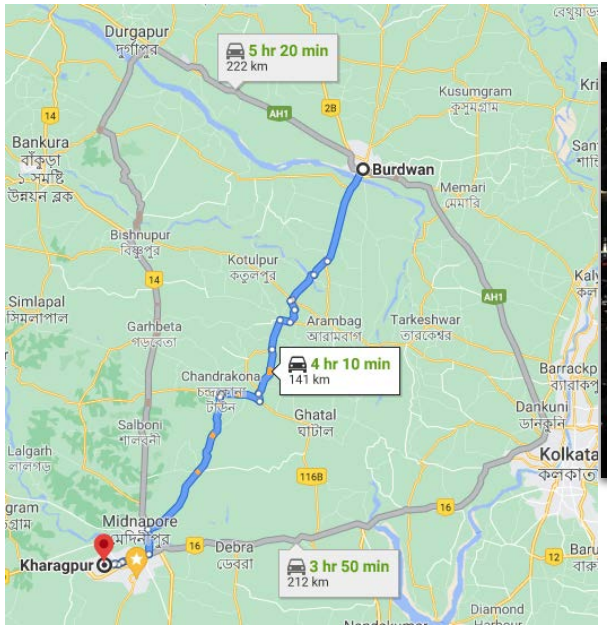
## Model



# Abstraction for Problem Solving



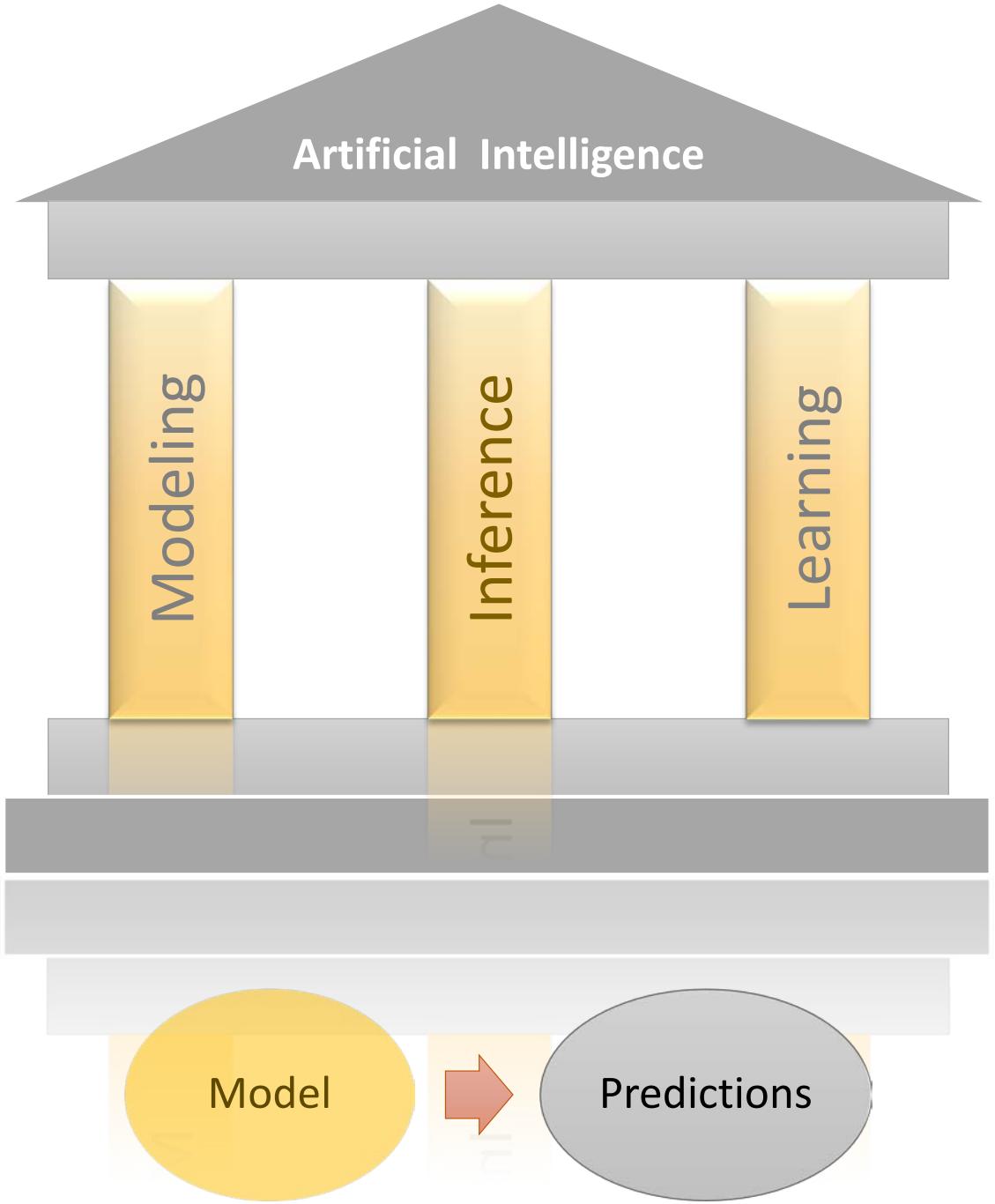



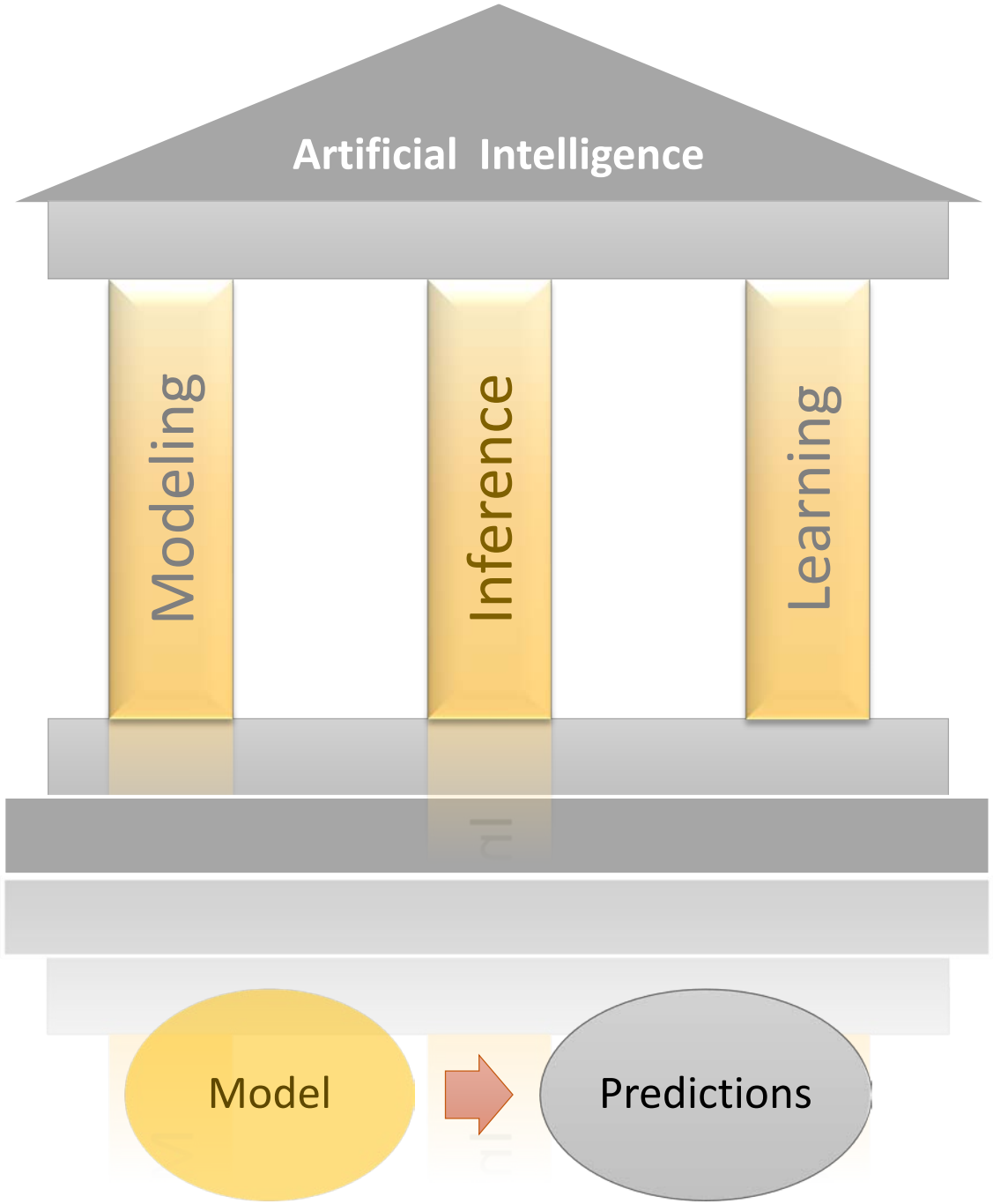




``… [the process of] abstraction is the essence of intelligence and the hard part of the problems being solved'' [Brooks, 1991]

# Problem Representation

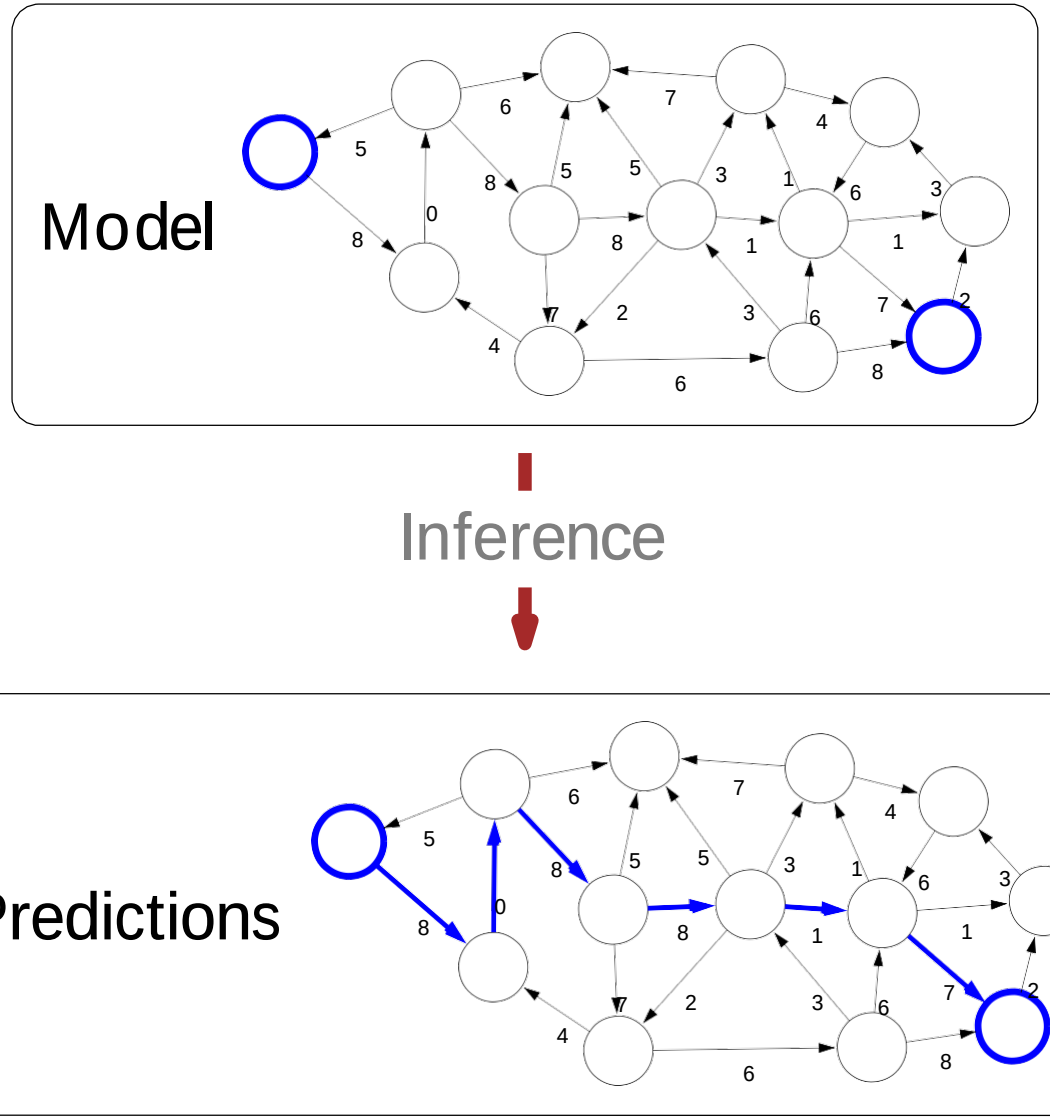
- Rich enough to express the knowledge needed to solve the problem
- Amenable to efficient computation

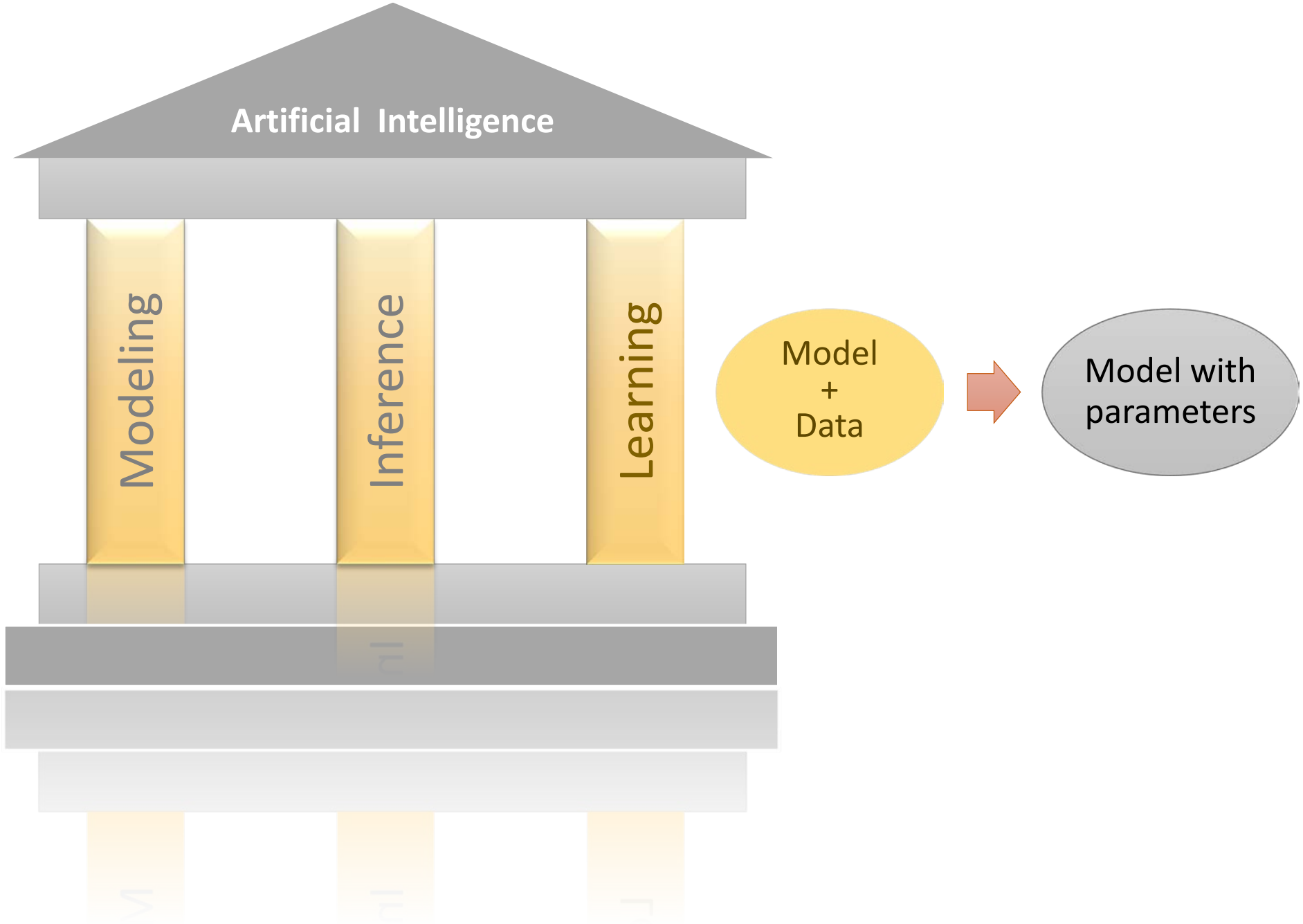

Artificial Intelligence
Modeling
Inference
Learning
Model
Predictions




Separate **what** to compute (**modelling**) from **how** to compute it (**algorithms**)

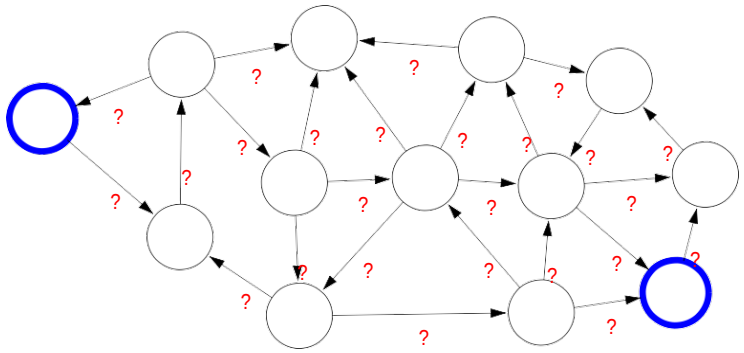
# Inference




Artificial Intelligence
Modeling
Inference
Learning
Model
+
Data
Model with
parameters

# Learning

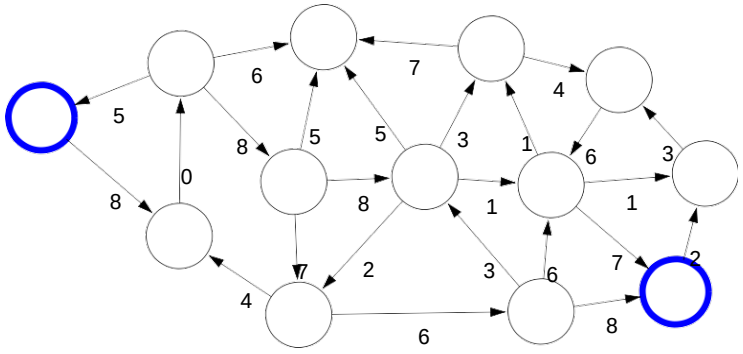
Model without parameters



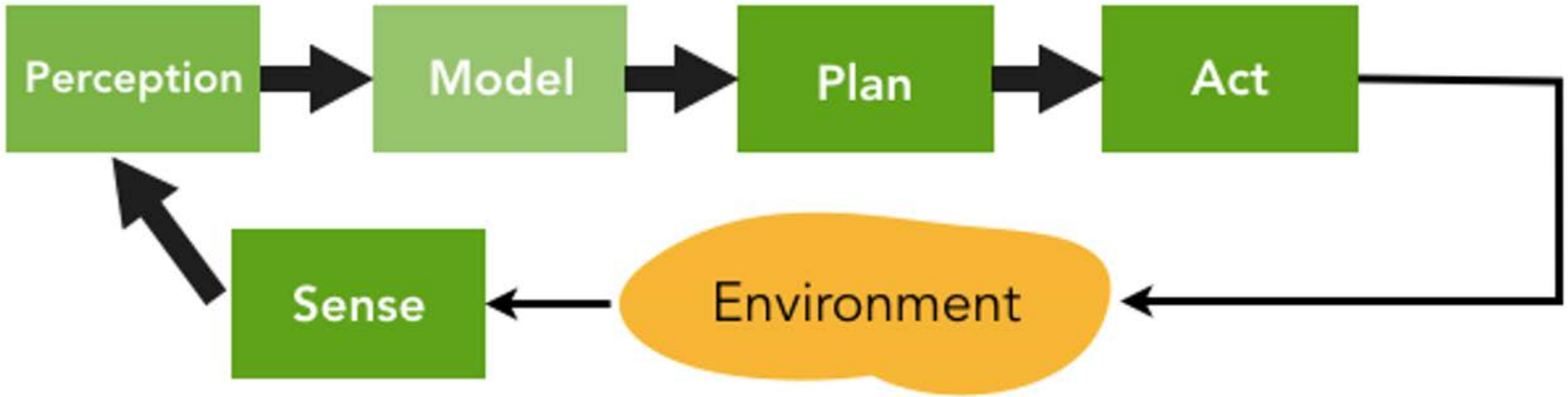
+data

**Learning**

Model with parameters

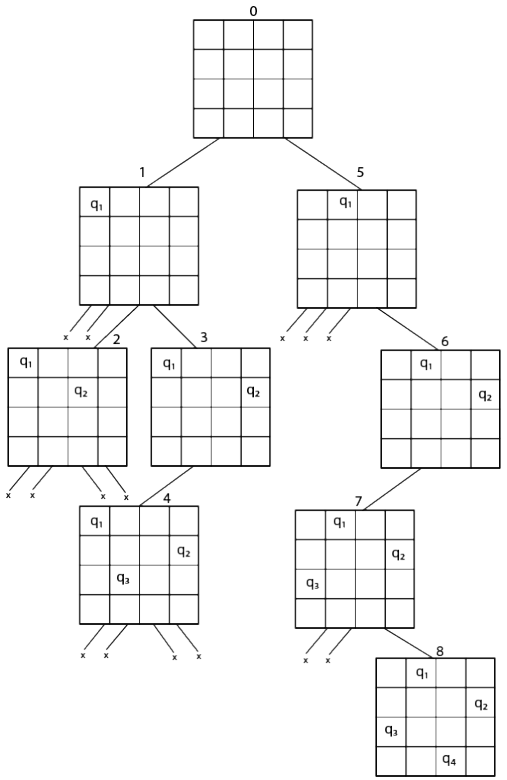


# Classical AI

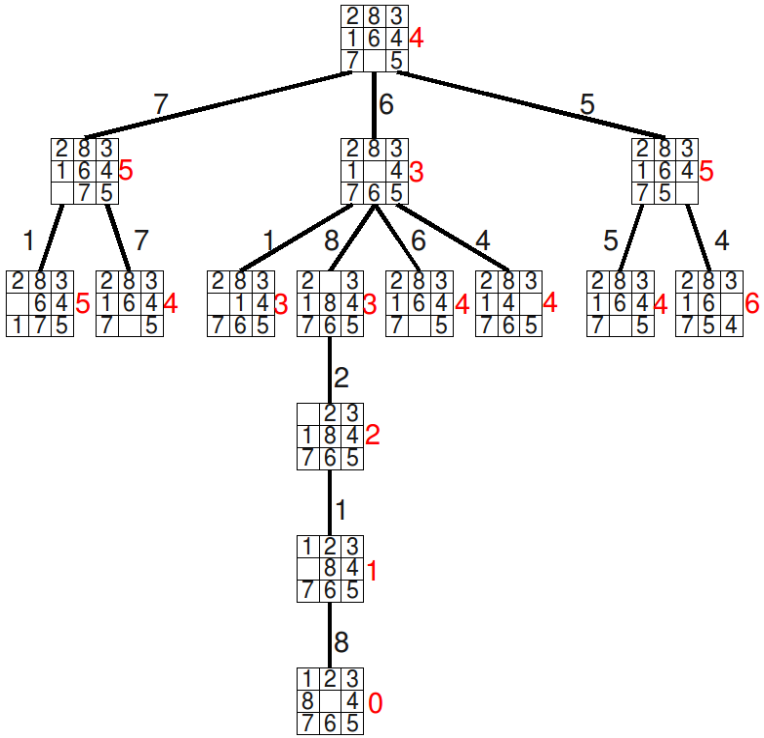


# State Based Models

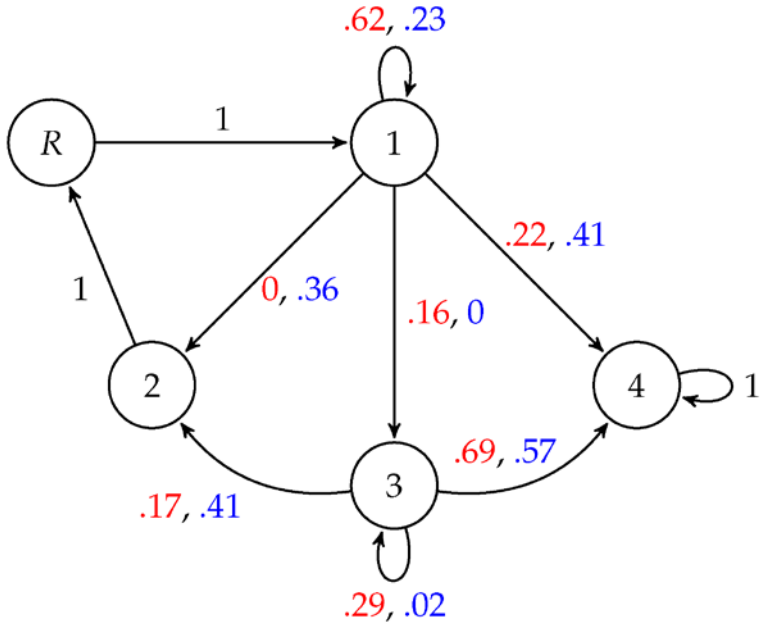
## Search problems



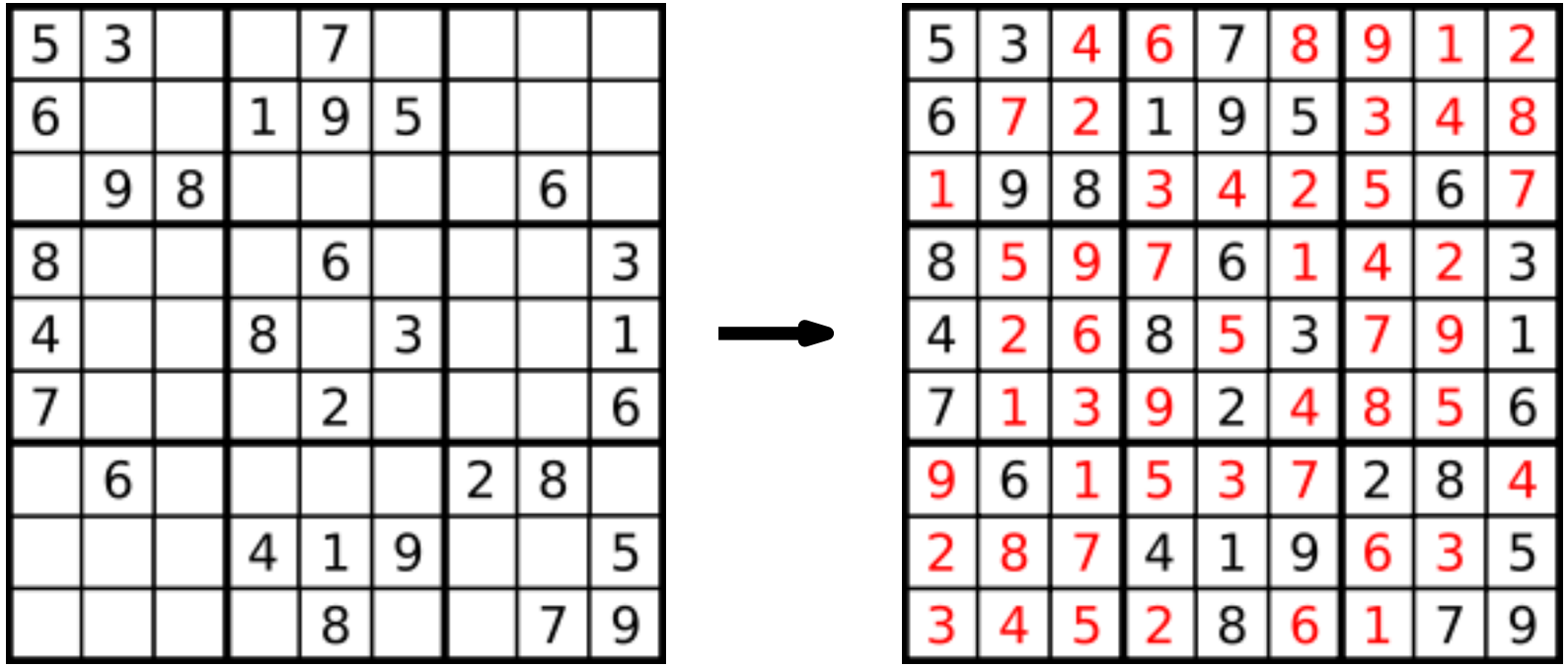
## Adversarial games



## Markov Decision Processes



# Variable based Models



| 5 | 3 |  |  | 7 |  |  |  |  |
|---|---|---|---|---|---|---|---|---|
| 6 |  |  | 1 | 9 | 5 |  |  |  |
|  | 9 | 8 |  |  |  |  | 6 |  |
| 8 |  |  |  | 6 |  |  |  | 3 |
| 4 |  |  | 8 |  | 3 |  |  | 1 |
| 7 |  |  |  | 2 |  |  |  | 6 |
|  | 6 |  |  |  |  | 2 | 8 |  |
|  |  |  | 4 | 1 | 9 |  |  | 5 |
|  |  |  |  | 8 |  |  | 7 | 9 |

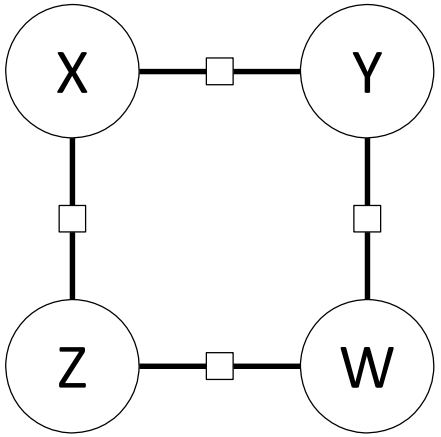
| 5 | 3 | 4 | 6 | 7 | 8 | 9 | 1 | 2 |
|---|---|---|---|---|---|---|---|---|
| 6 | 7 | 2 | 1 | 9 | 5 | 3 | 4 | 8 |
| 1 | 9 | 8 | 3 | 4 | 2 | 5 | 6 | 7 |
| 8 | 5 | 9 | 7 | 6 | 1 | 4 | 2 | 3 |
| 4 | 2 | 6 | 8 | 5 | 3 | 7 | 9 | 1 |
| 7 | 1 | 3 | 9 | 2 | 4 | 8 | 5 | 6 |
| 9 | 6 | 1 | 5 | 3 | 7 | 2 | 8 | 4 |
| 2 | 8 | 7 | 4 | 1 | 9 | 6 | 3 | 5 |
| 3 | 4 | 5 | 2 | 8 | 6 | 1 | 7 | 9 |

Goal: put digits in blank squares so each row, column, and 3x3 sub-block has digits 1–9

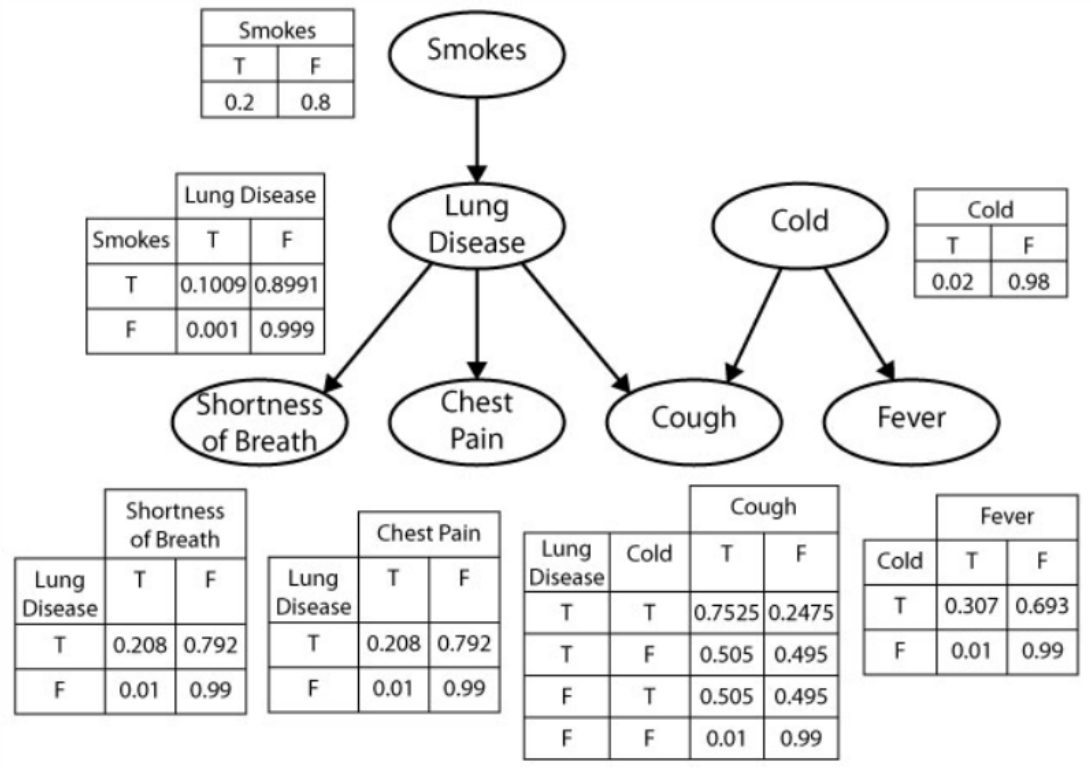
Key: order of filling squares doesn't matter in the evaluation criteria!

# Variable-based models

Constraint satisfaction problems: (e.g., Sudoku, scheduling)




Bayesian networks:

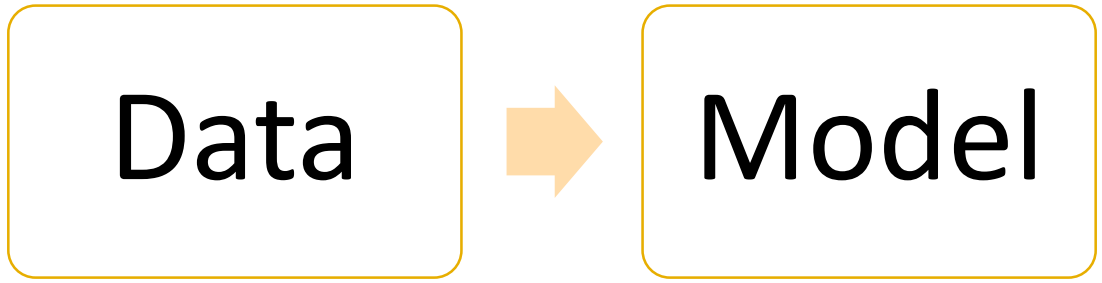


# Logic: Representation and Inference

- The rice harvest is good, but there is not enough water.
- If there is a lot of rain or not a lot of sun, then there is enough water.
- Therefore there is not a lot of sun.

- Someone from Kgp stole the crown
- An honest person does not steal
- All smart people are honest
- Is everyone at Kgp smart?

# Learning




- Requires a leap of faith: generalization

# What is intelligence?

- Ability to perceive and act in the world
- Representation of knowledge
- Reasoning: proving theorems, medical diagnosis
- Behaviour: Decision Theory, Learning, Planning, Scheduling, Search
  - Planning: take decisions
  - Learning and Adaptation: recommend movies, learn traffic patterns
- Interaction
- Applications

# AI optimism

- AI has enjoyed rapid progress and visibility.
- Top firms -  Google, Facebook, Amazon and Baidu have got into an AI arms race
- AI is taking tasks that used to be things which only people could do and making them amenable to machines.
  - The ocean of data generated by the internet-connected computers, and devices
  - The huge amounts of computing power
- creating algorithms that are more and more capable of understanding languages, recognizing images, …

# Technical progress

- **Generative systems:** AI systems can compose text, audio, and images to a sufficiently high standard
- **Natural Language Processing (NLP)** Progress in NLP has been so swift that technical advances have started to outpace the benchmarks to test for them.
- Computer Vision:
- **Machine learning in healthcare and biology**: DeepMind's AlphaFold applied deep learning technique to make a significant breakthrough in the decades-long biology challenge of protein folding. Scientists use ML models to learn representations of chemical molecules for more effective chemical synthesis planning. PostEra, an AI startup used ML-based techniques to accelerate COVID-related drug discovery during the pandemic.

# AI: A threat?

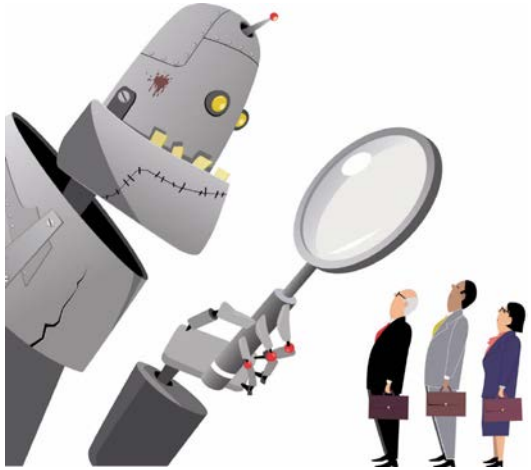
- Elon Musk described artificial intelligence (AI) as “summoning the demon”, and the creation of a rival to human intelligence as probably the biggest threat facing the world.
- Nick Bostrom, a philosopher at the University of Oxford who helped develop the notion of “existential risks”—those that threaten humanity in general—counts advanced artificial intelligence as one such, alongside giant asteroid strikes and all-out nuclear war.
- Lord Rees, who used to run the Royal Society, Britain’s foremost scientific body, has since founded the Centre for the Study of Existential Risk, in Cambridge, which takes the risks posed by AI just as seriously

# Other difficult questions…

- Who is liable if a robot driver has an accident?
- Will machines surpass human intelligence (in all ways)?
- Would such machines have conscious existence? Rights?
- What is a mind?
- How can a physical object have a mind?
- Can we build a mind?

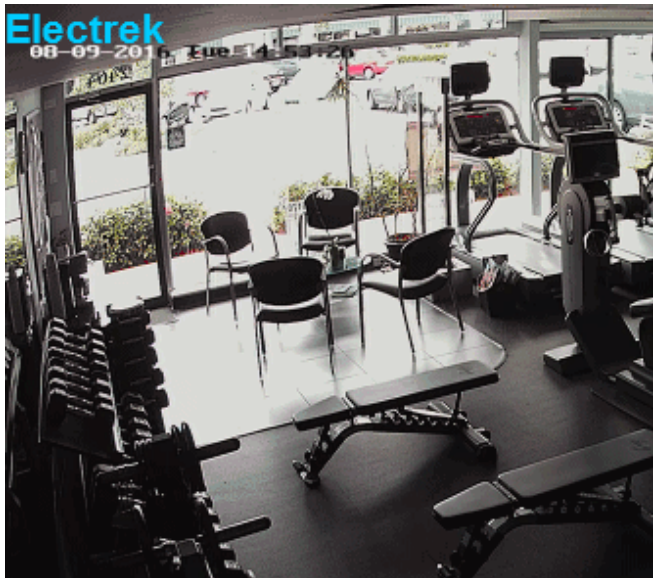
# Should We Worry about Today's A.I.?

## Bias



## Weapons

## Liability




## Jobs

Images:
https://medium.com/@turalt/ai-isnt-biased-we-are-b74ec94d1698
http://futureoflife.org/2016/09/20/podcast-what-is-nuclear-risk/
https://electrek.co/2016/09/25/tesla-model-s-crashes-into-gym-driver-claims-autonomous-acceleration-tesla-says-drivers-fault/
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