THE UNIVERSITY of EDINBURGH

usher institute

Better health, better futures

AI: From Zero to Aha!

Erfan Loweimi

Research Fellow in Machine Learning
Centre for Medical Informatics, Usher Institute
University of Edinburgh

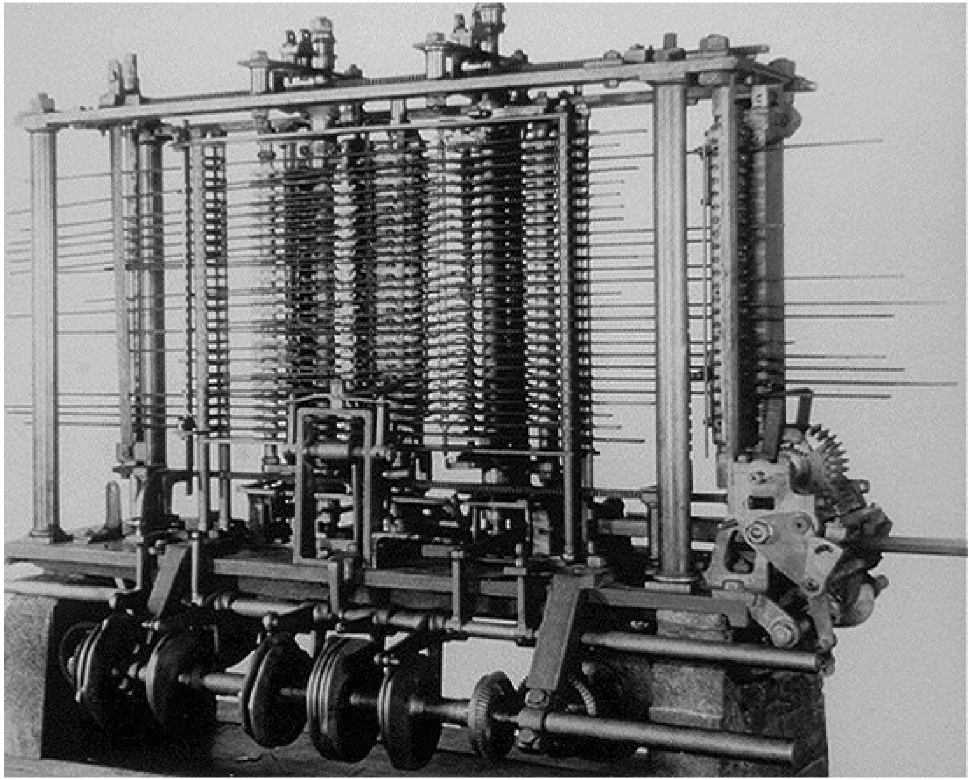
NASA's James Webb Space Telescope, deepest and sharpest image of the universe

What is the **most complex creation** in the known universe?

The Most Complex Creation in the Known Universe ...

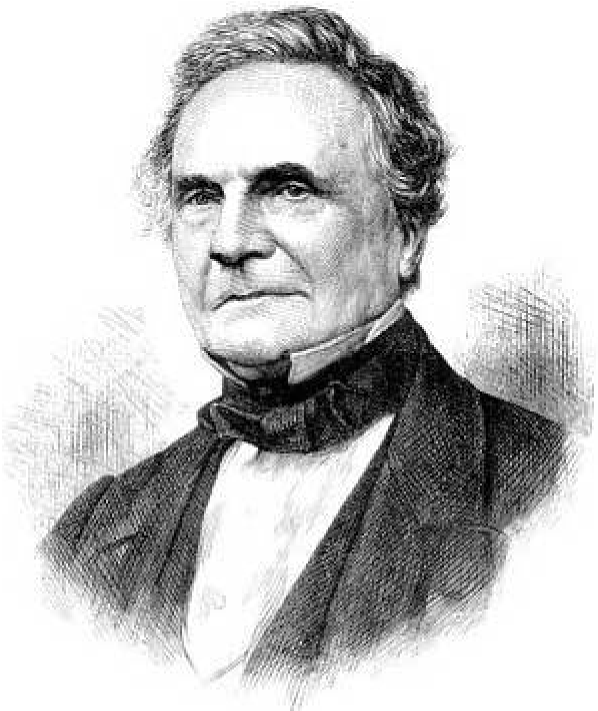
Human Brain

- 86B Neurons
- 86,000B Synapses



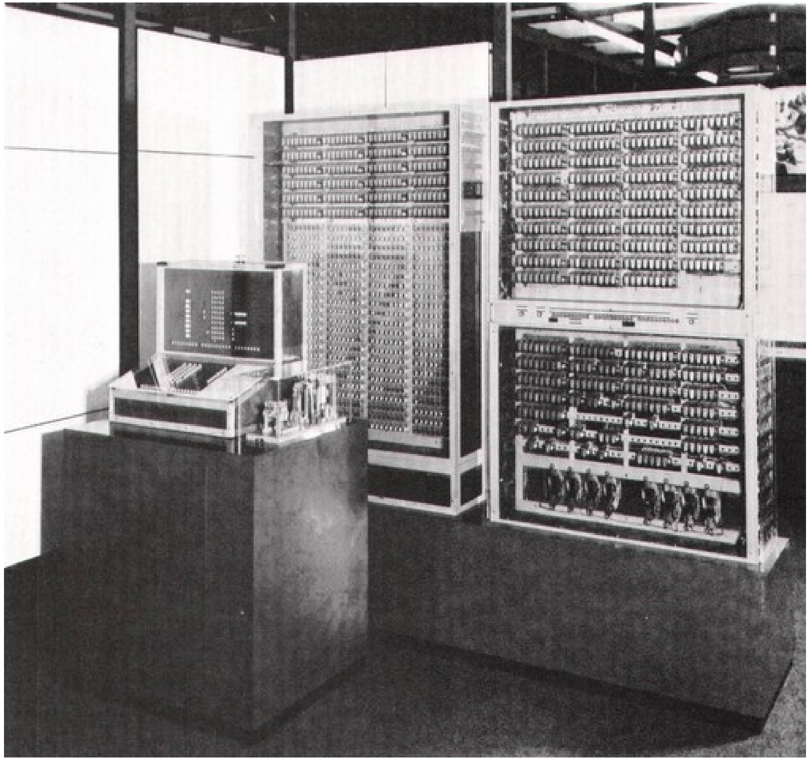
Difference Engine

(Mechanical Computer, Mid 19th century)



Charles Babbage (1791-1871)

[Father of the computer]

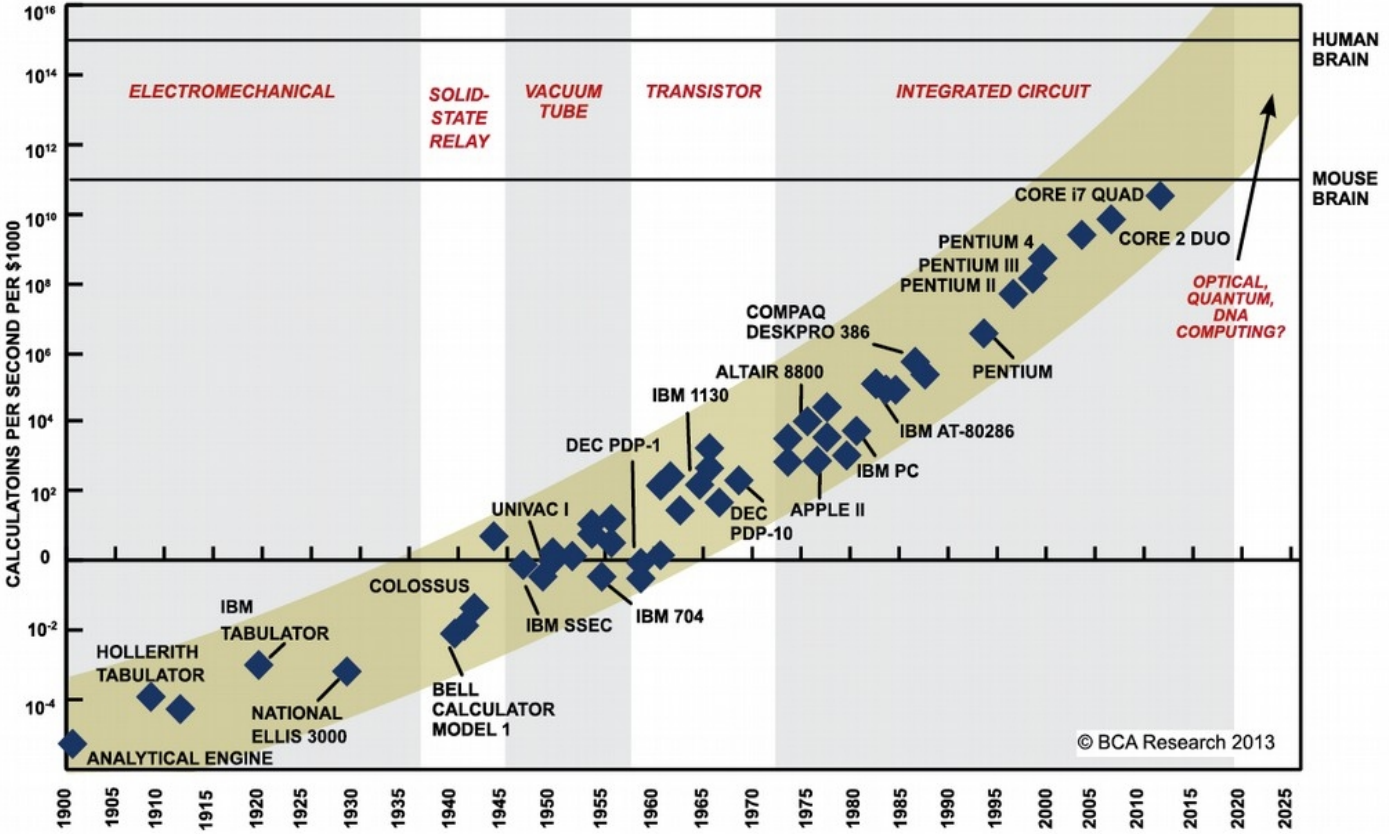


Z3

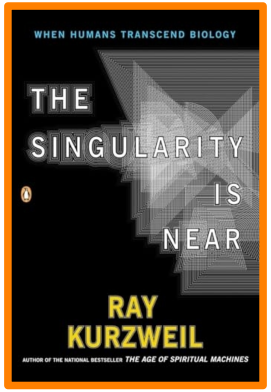
(ElectroMechanical Computer, 1941)

Konrad Zuse (1910-1995)

ENIAC
(Electronic Numerical Integrator and Computer, 1945)

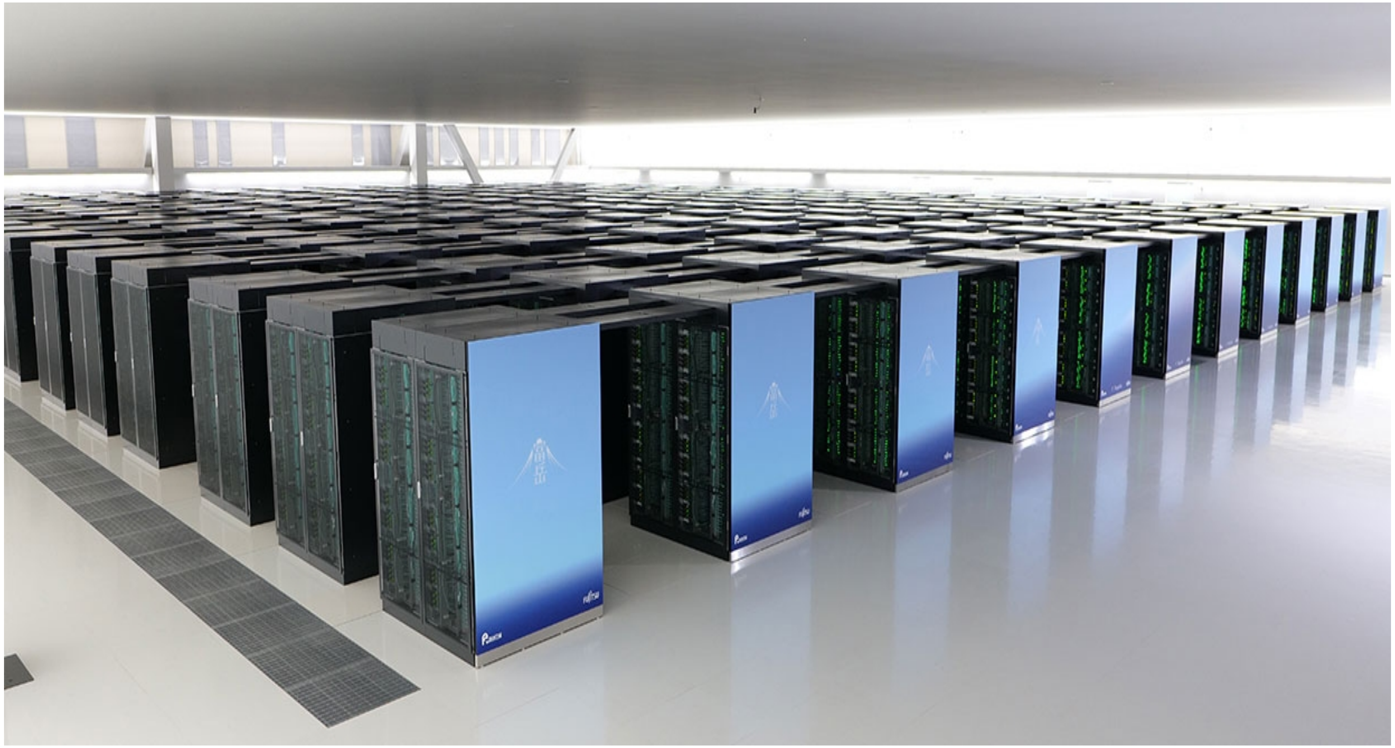


SOURCE: RAY KURZWEIL, "THE SINGULARITY IS NEAR: WHEN HUMANS TRANSCEND BIOLOGY", P.67, *THE VIKING PRESS*, 2006. DATAPOINTS BETWEEN 2000 AND 2012 REPRESENT BCA ESTIMATES.



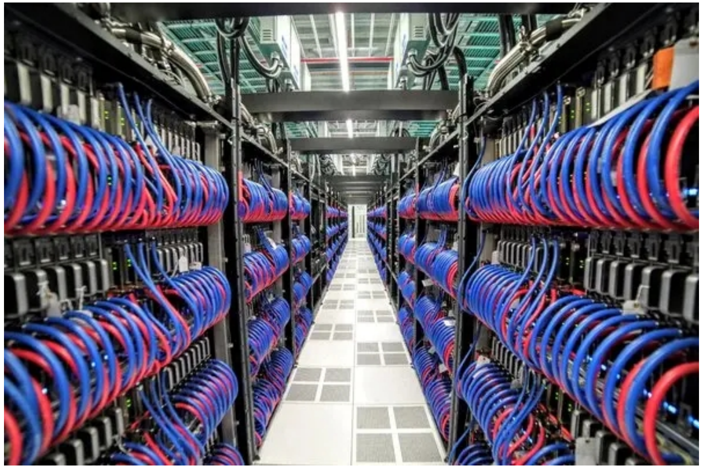
Computation became *exponentially* faster and cheaper

Supercomputers: Fugaku



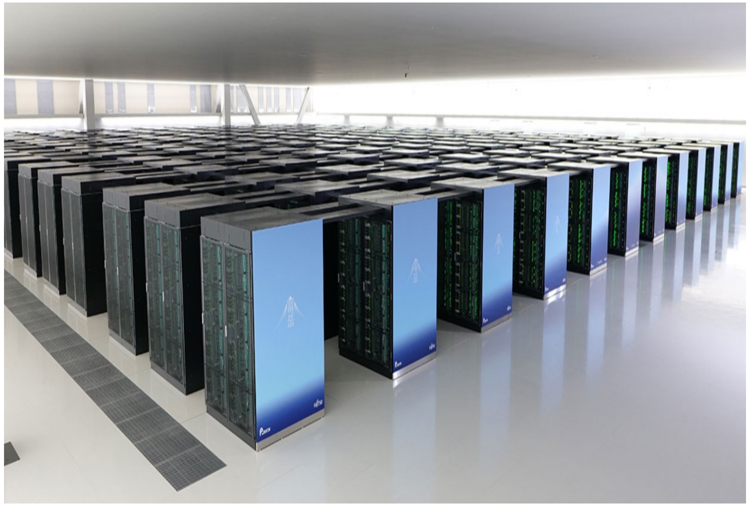
~ 0.5 x 10^{18} FLOPS (Rmax)
7.63 x 10^{6} CPU Cores (ARM)

Supercomputers: Frontier



~ 1.102 x 10^{18} FLOPS (Rmax)
600k CPU + 8.1M GPU Cores (AMD)

Brain vs Supercomputers



0.5 **x**

x = 1 x 10^{18} FLOPS

1.1 **x**

FLOPS: Floating-point operations per second

Problems to Solve

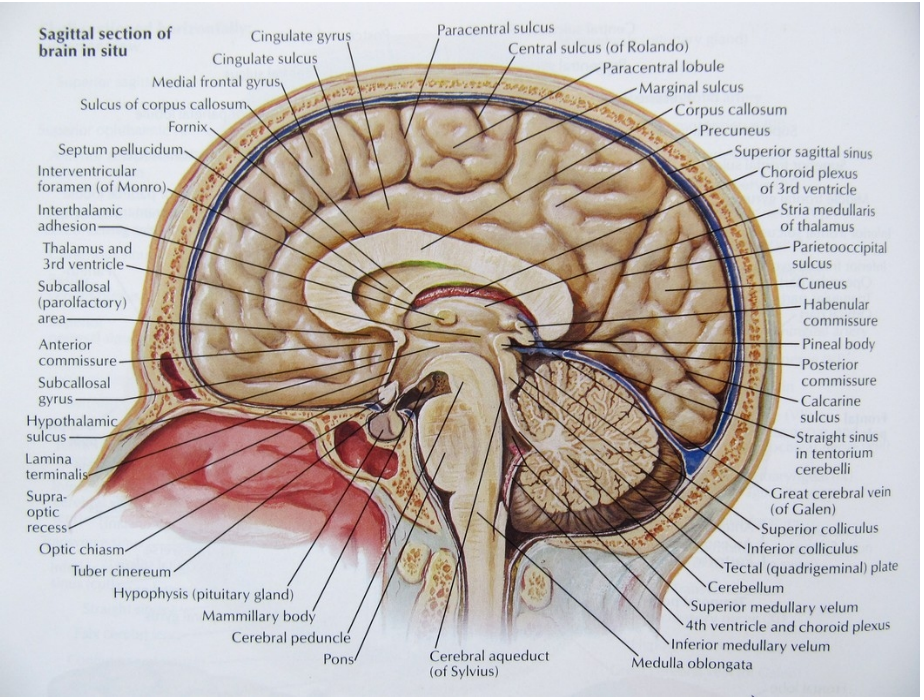
Type I
(e.g., Multiplication)

$$\begin{array}{r} 568923471609458.2341112 \\ \times\ 973241231.2431506879416 \\ \hline \end{array}$$

A Well-Defined Problem
with Clear Solution Steps

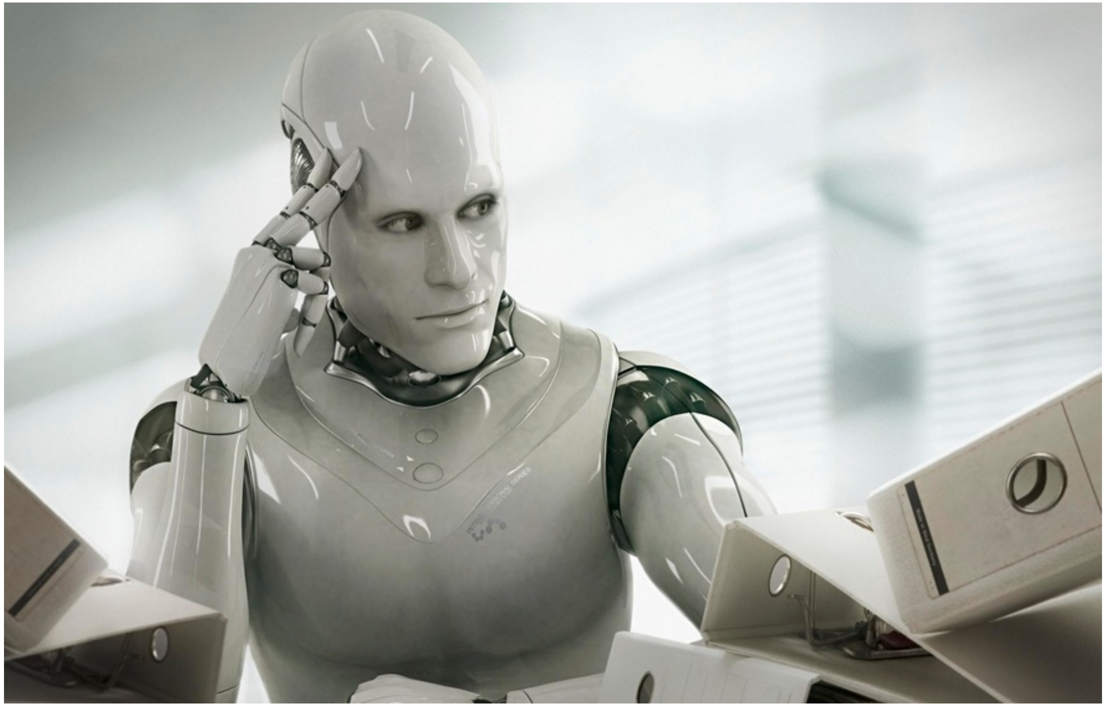
Type II
(e.g., Identification)

Pattern Recognition ...
Solution Steps???



Physiology

Engineering

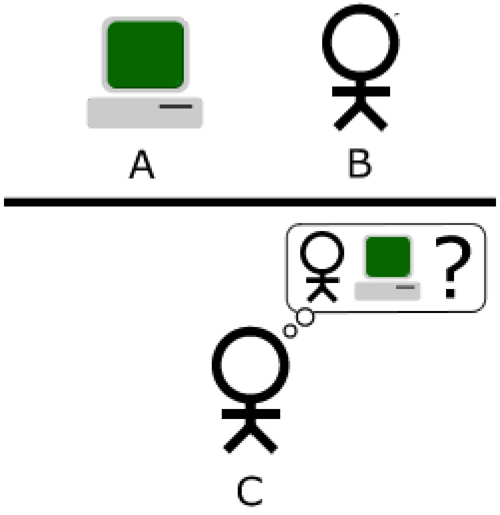


Artificial Intelligence

Engineering

What does Intelligence Mean?

Turing Test
(The Imitation Game)



Turing, A.M. (1950). Computing machinery and intelligence. Mind, 59, 433-460.

COMPUTING MACHINERY AND INTELLIGENCE

By A. M. Turing

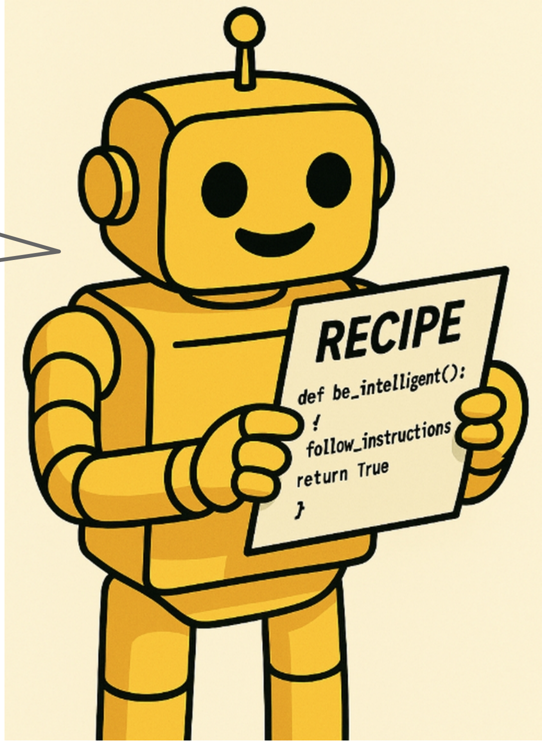
1. The Imitation Game

I propose to consider the question, "Can machines think?" This should begin with definitions of the meaning of the terms "machine" and "think."

Alan Turing (1912-1954)
[Father of the computer science]

How to Build an Intelligent Machine?

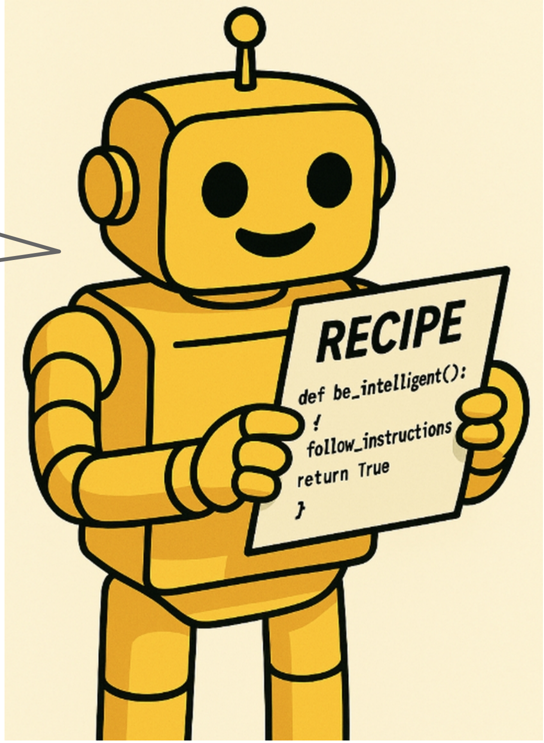
Hey Machine!
Time to be intelligent;
follow this **Recipe** ...



Generated by ChatGPT
(DALL·E 3, OpenAI)

How to Build an Intelligent Machine?

Hey Machine!
Time to be intelligent;
follow this **Recipe** …



AI as a **Programming** Problem …

Generated by ChatGPT
(DALL·E 3, OpenAI)

How to Build an Intelligent Machine?

- Explicit Recipe (Explicit Programming)

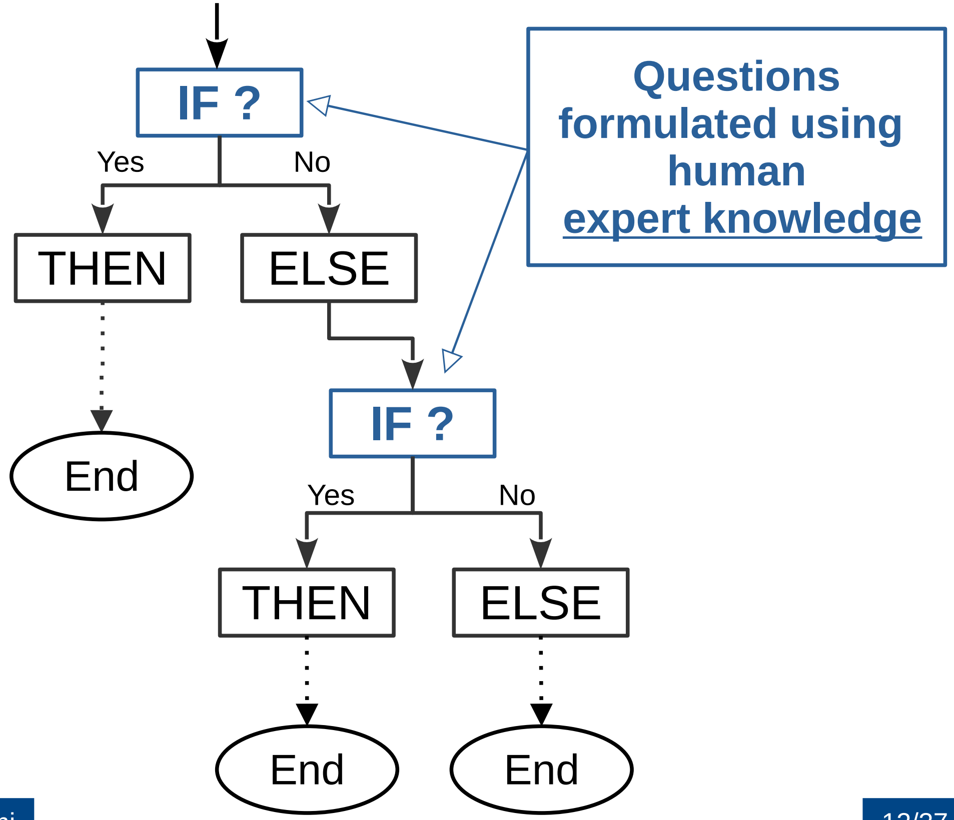
- Implicit Recipe (Implicit Programming)

Explicit Programming

Decision Making **Rules**

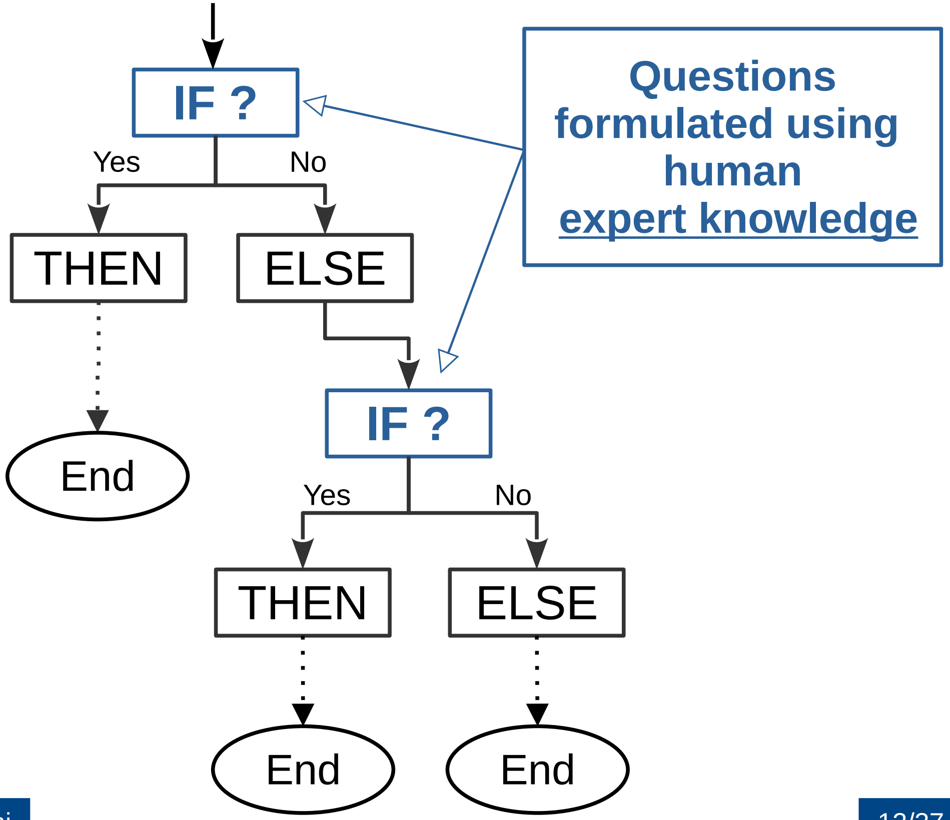
→

Hardcoded Knowledge

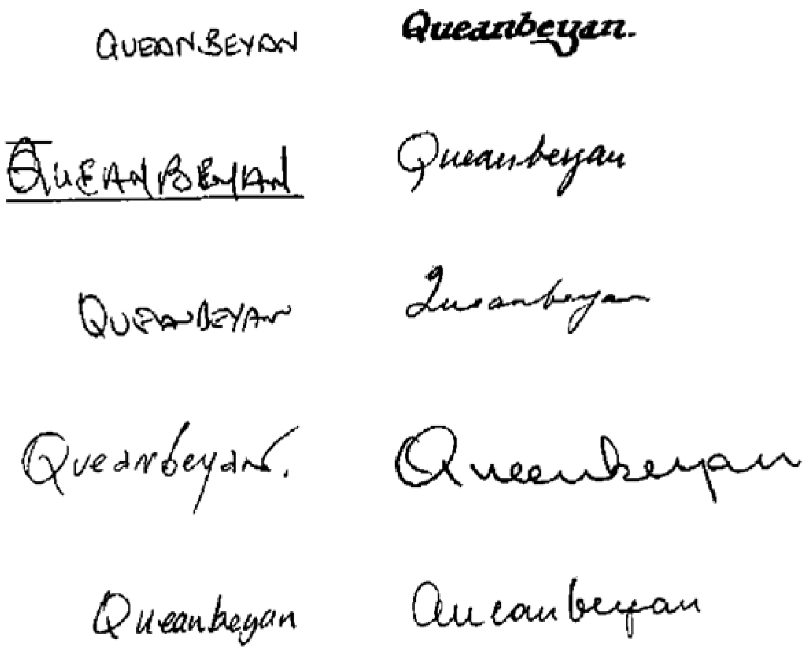


Explicit Programming

Rule-based (Expert) Systems

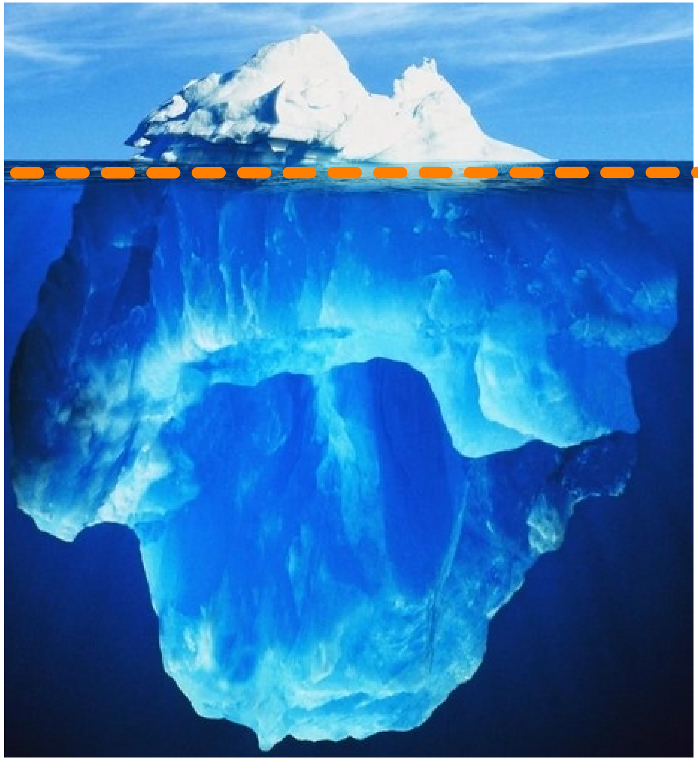


Expert Systems’ Achilles Hill



Variability & **Scalability**

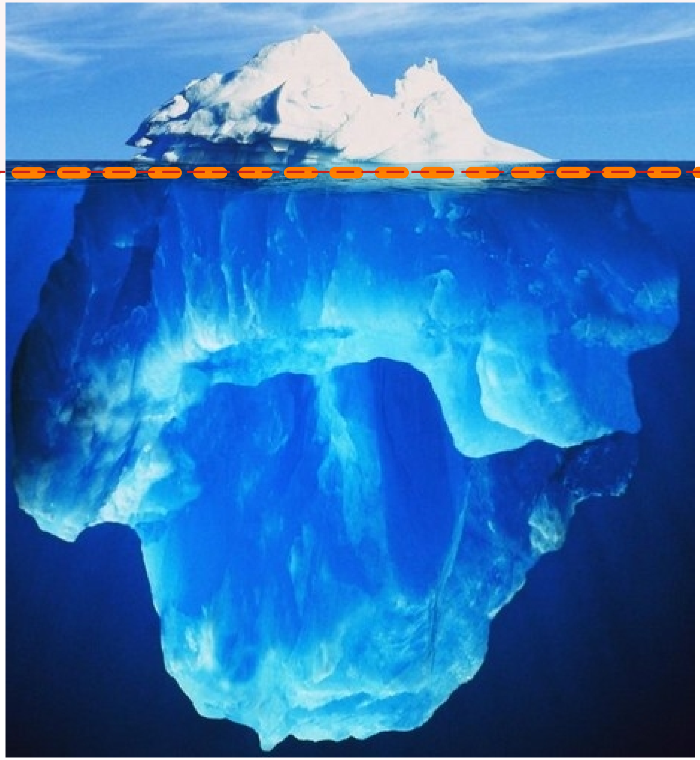
=> Poor generalisation



Visible

Invisible

Explicit
Programming



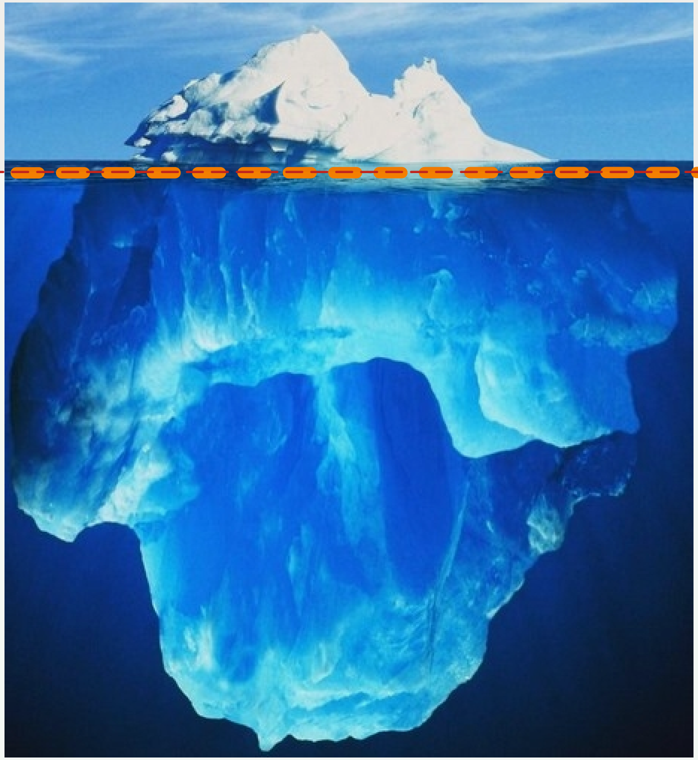
Visible

Invisible

Explicit Programming

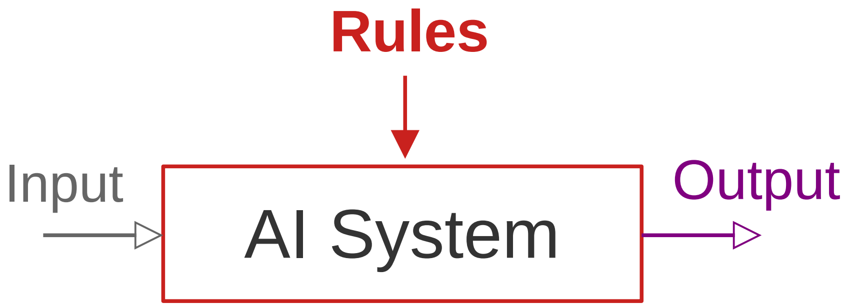
Visible

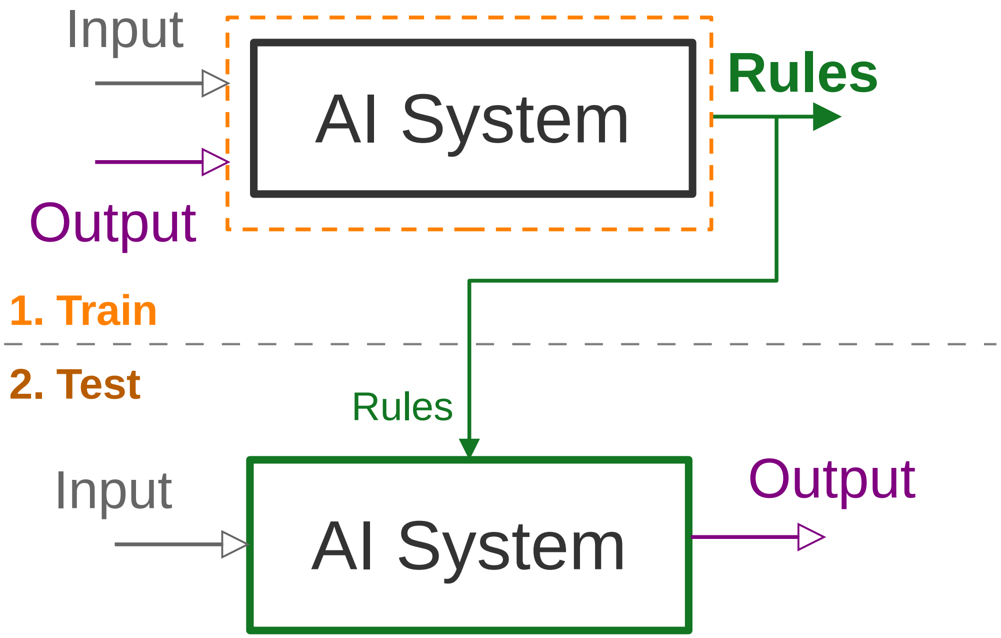
Invisible



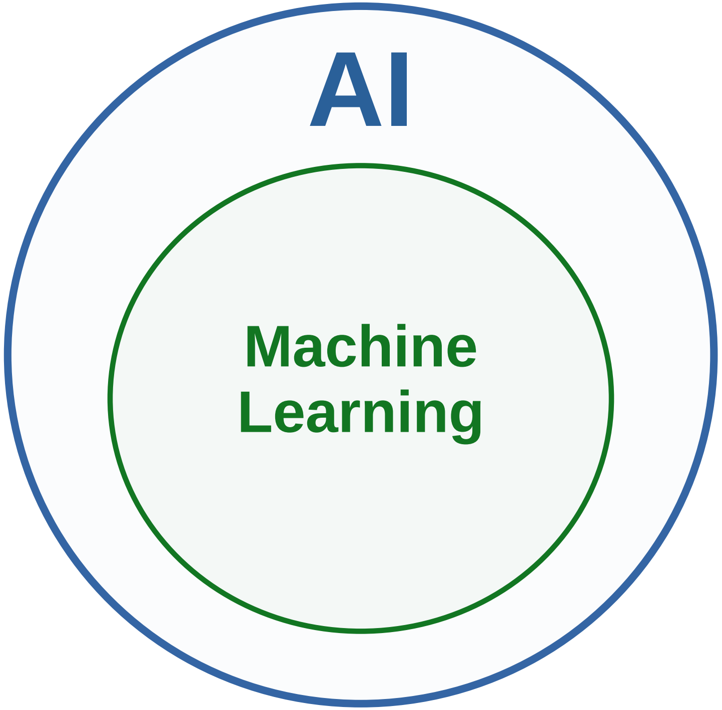
Implicit Programming

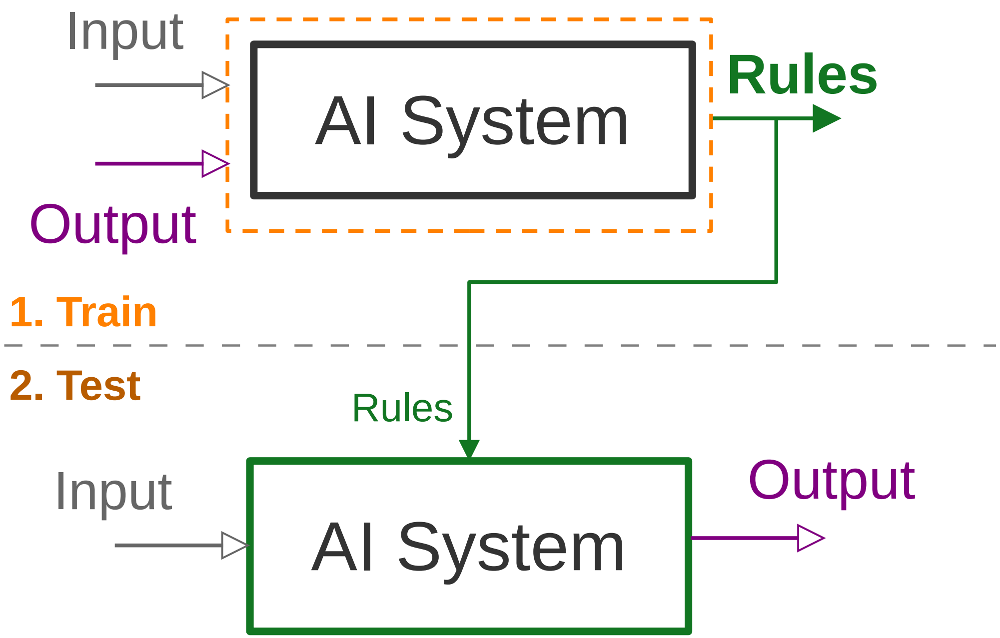
Explicit vs Implicit Programming



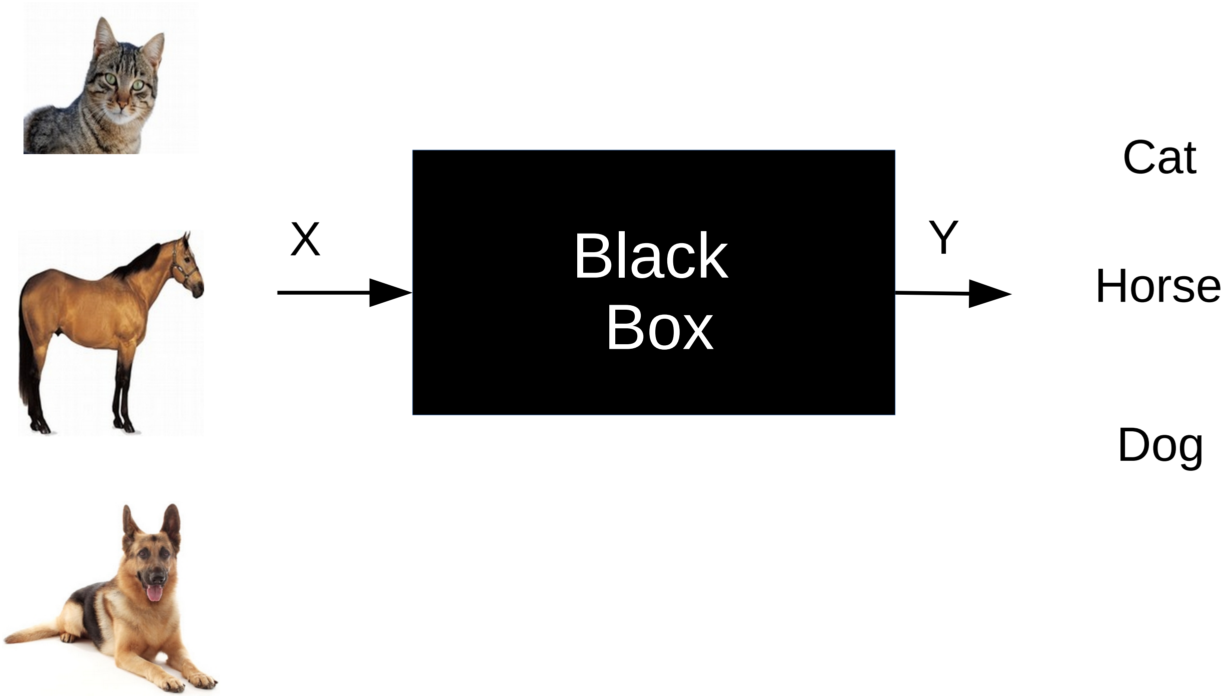


Implicit Programming → Machine Learning





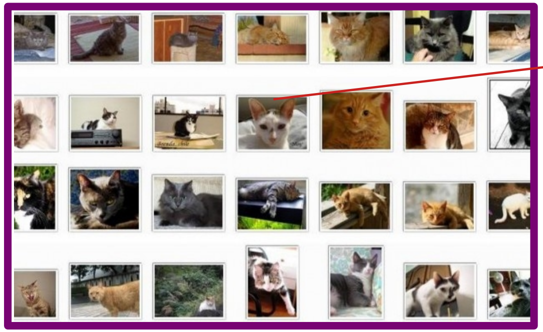
Machine Learning

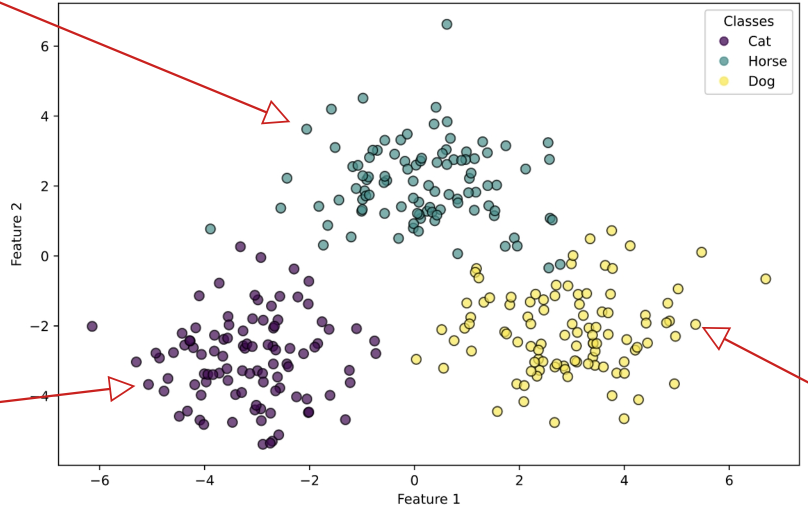


Machine Learning

Data (**Horse**)

Data (**Cat**)





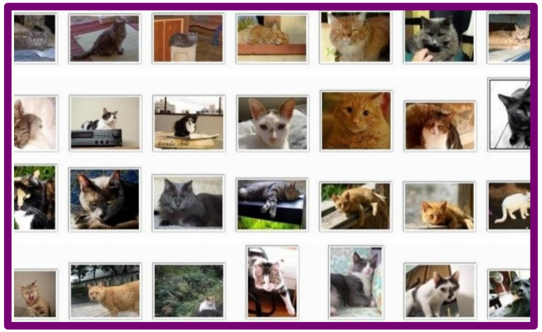
Data (**Dog**)

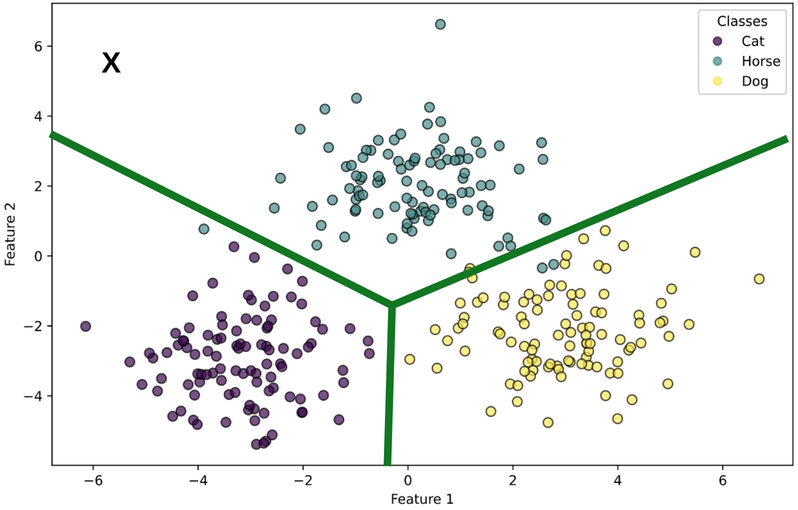
Data → **Feature Extraction** → Features

Machine Learning

Data (Horse)

Data (Cat)

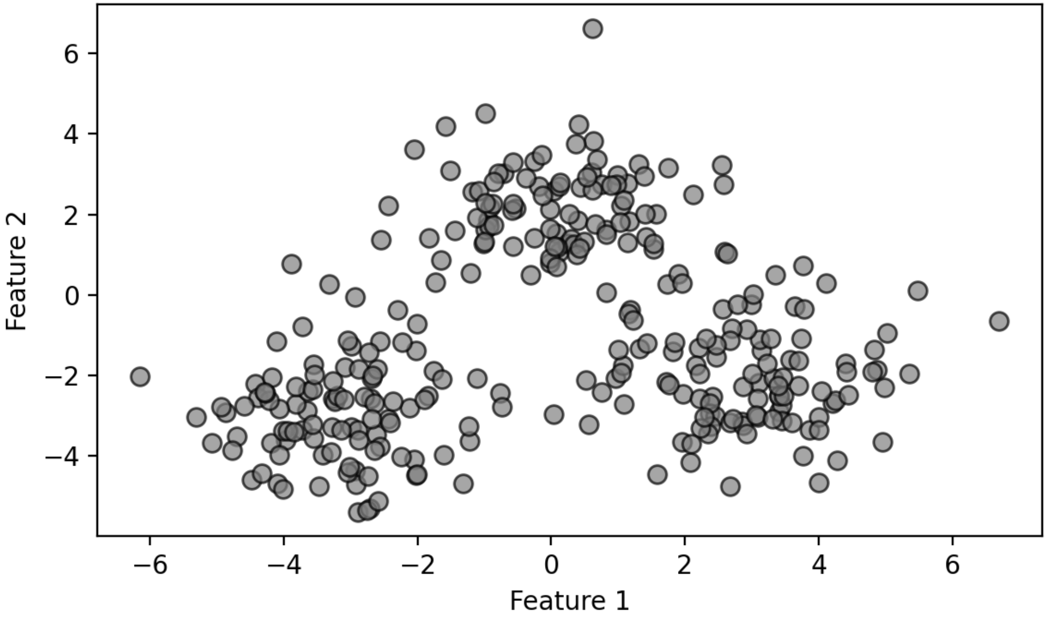




Decision Boundaries ≡ Rules

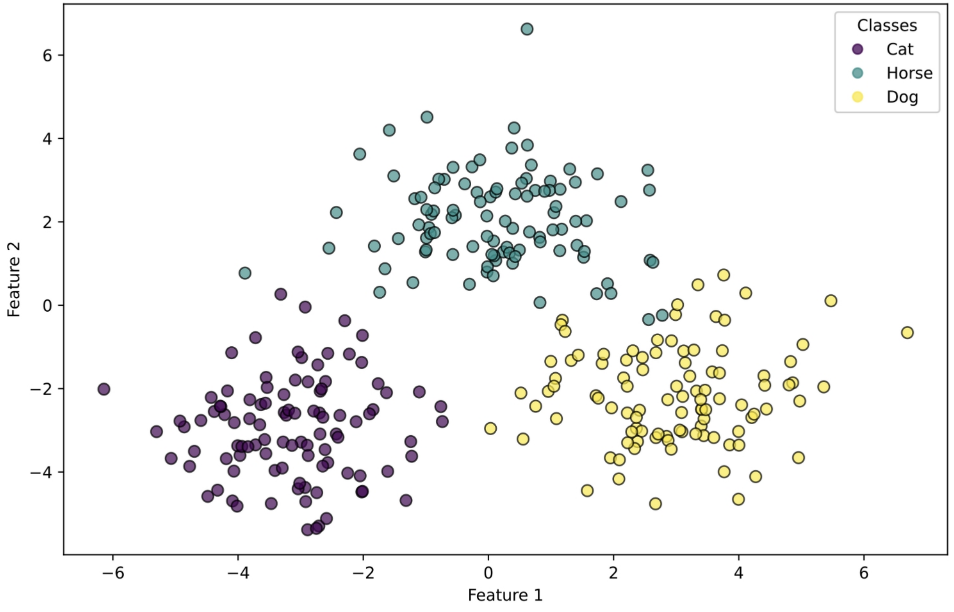
Data (Dog)

Machine Learning Paradigms

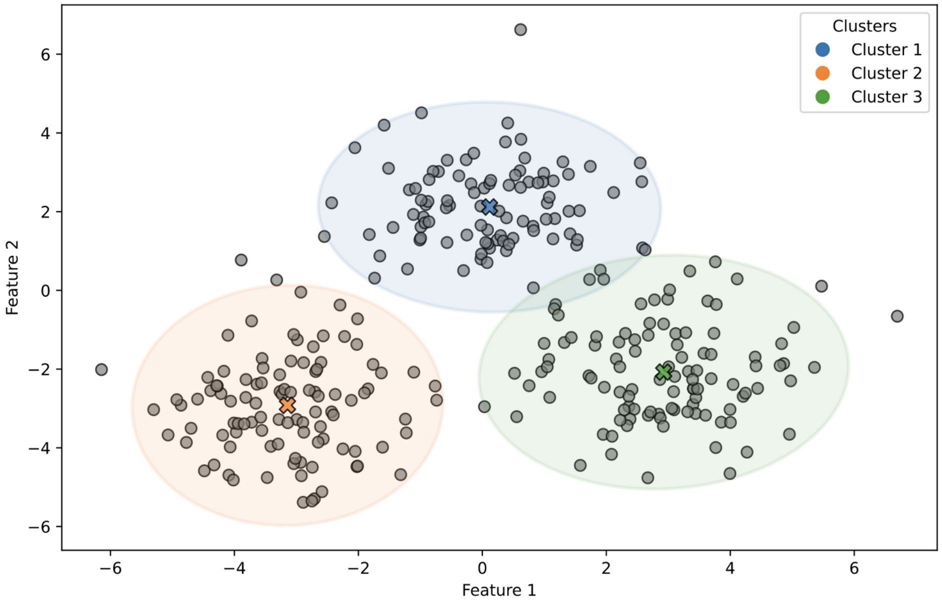


Supervised vs Unsupervised

Labels known
(classes)

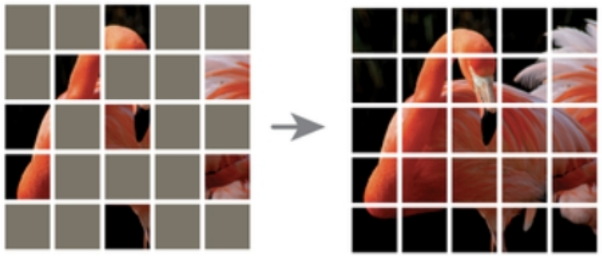


Labels unknown
(clusters)



Self-supervised Learning

- Train models to predict parts of input from other parts
- No manual labels → Data supervises itself
- Examples:
  - The cat [mask] on the mat



- Core to training LLMs, representation learning, ...

Importance of Paradigms

Reinforcement Learning
≡ cherry

Supervised Learning
≡ icing

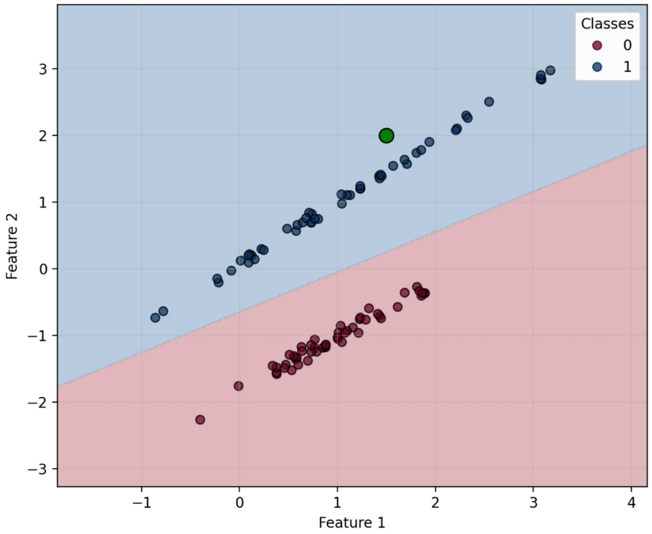
Self/unsupervised Learning
≡ cake base

Intelligence as a Cake

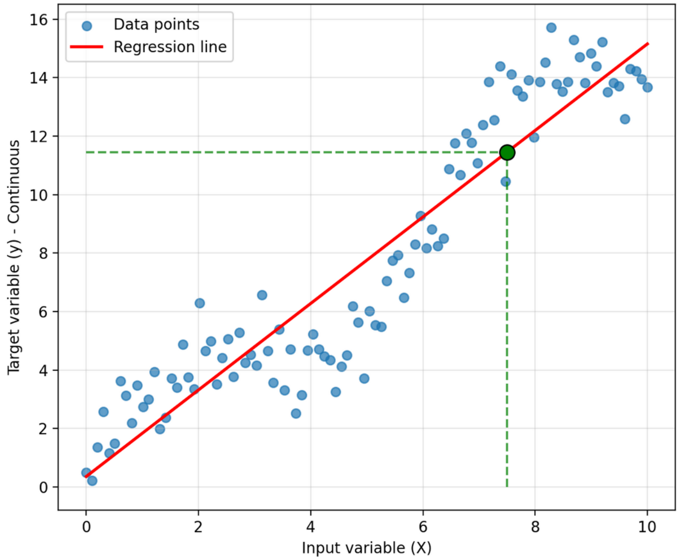
Yann LeCun
(Chief AI Scientist at Meta,
Prof. at NYU)

(Supervised)
Classification vs Regression

- Predict discrete categories

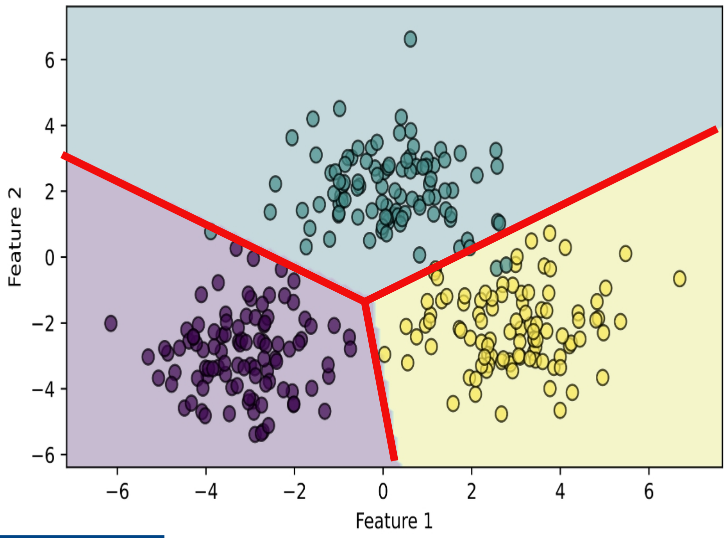


- Predict continuos values

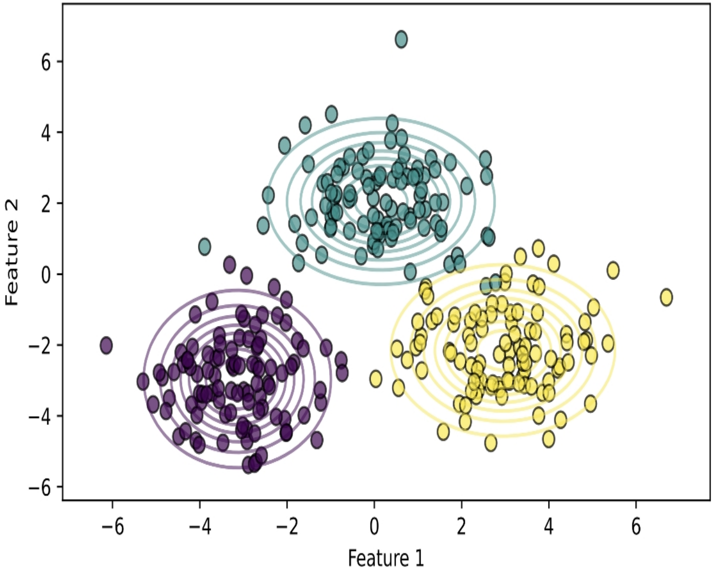


Discriminative vs Generative

- Learn decision boundaries
  - Classification

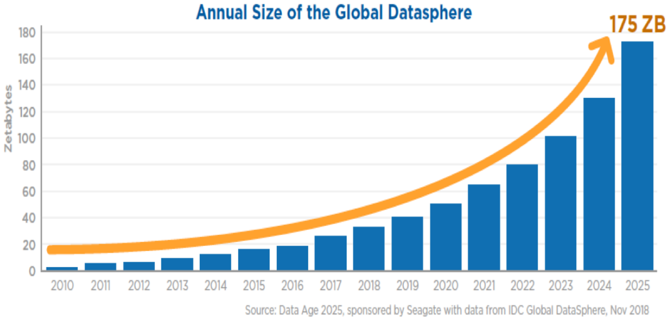


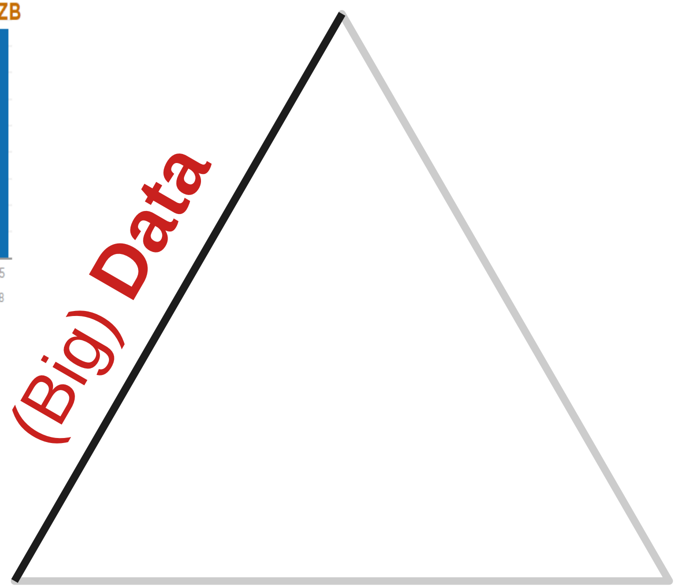
- Learn how data is generated
  - Generation & Classification



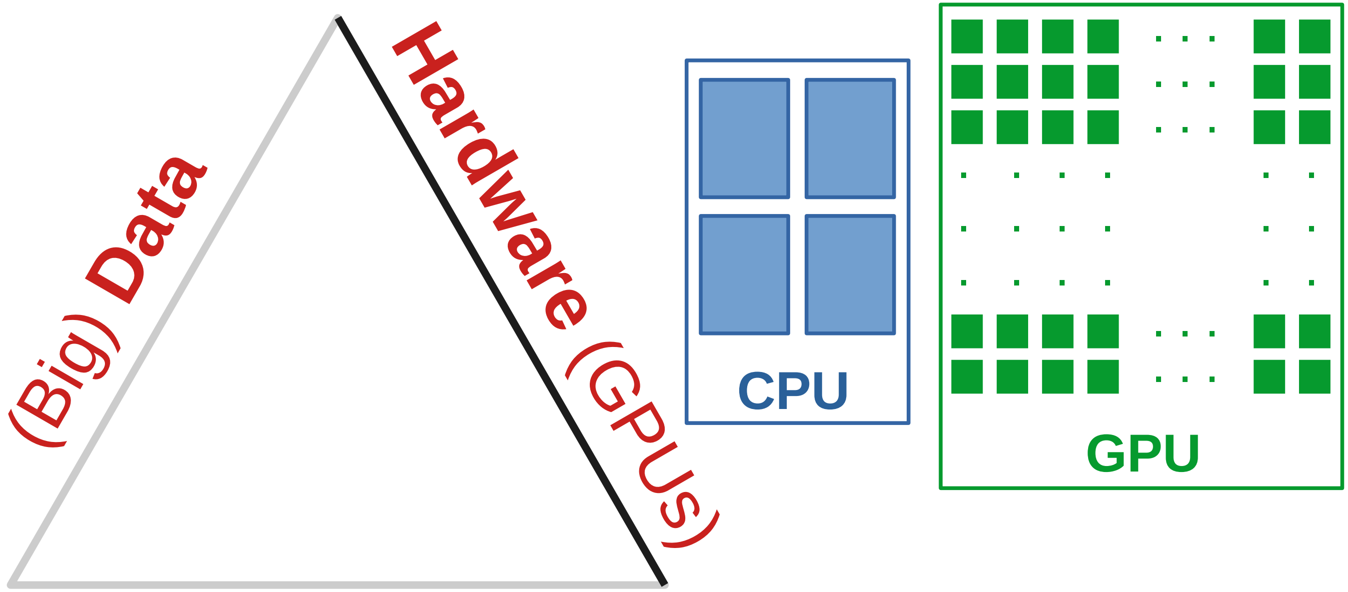
Why is AI BOOMING now?

Why is AI BOOMING now? (1)



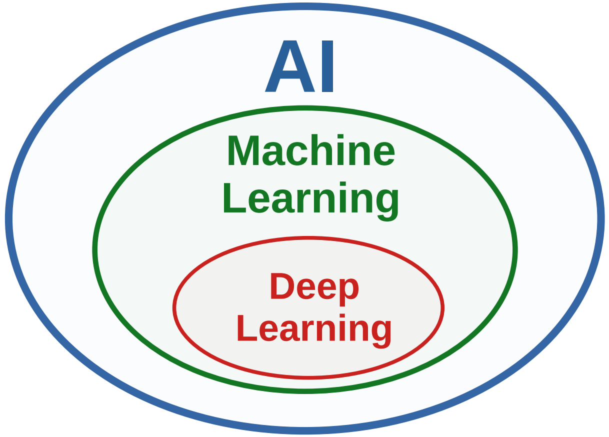


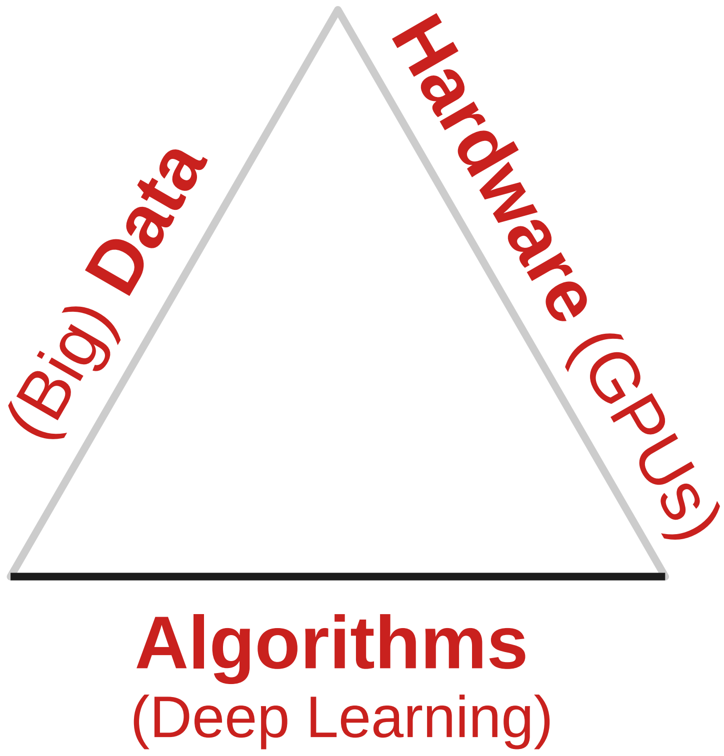
Why is AI BOOMING now? (2)



Sequential vs **Parallel**
Processing

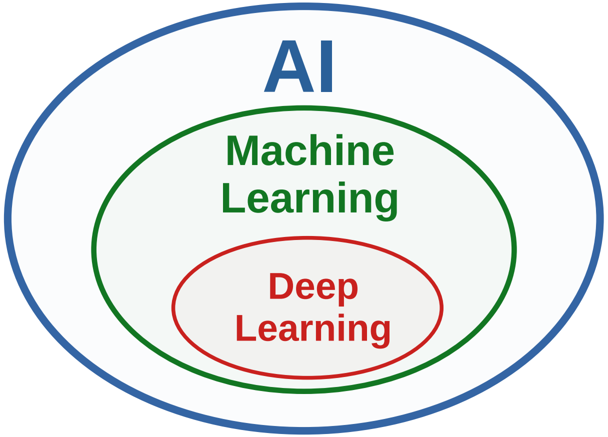
Why is AI BOOMING now? (3)

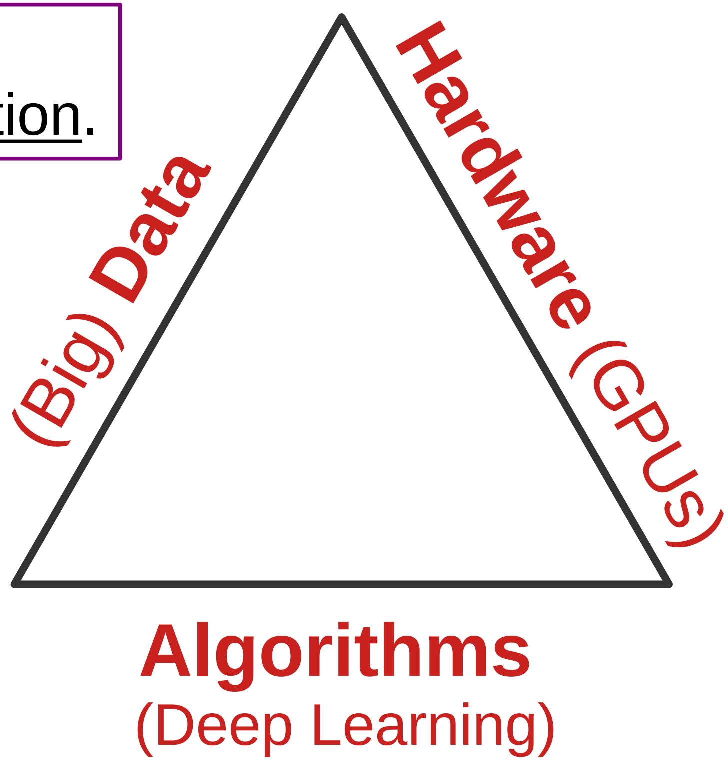




Why is AI BOOMING now? (3)

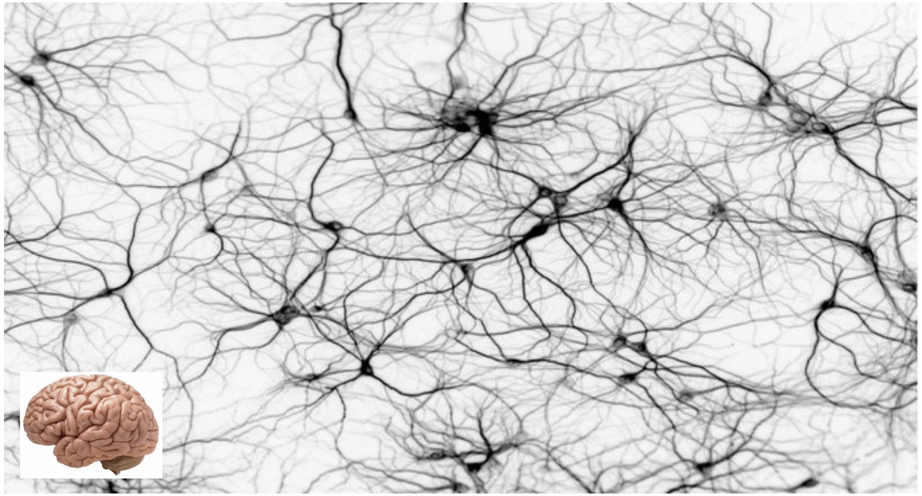
<u>Deep learning</u> is *extremely* hungry for <u>data</u> & <u>computation</u>.





Deep Learning ≡ DNN

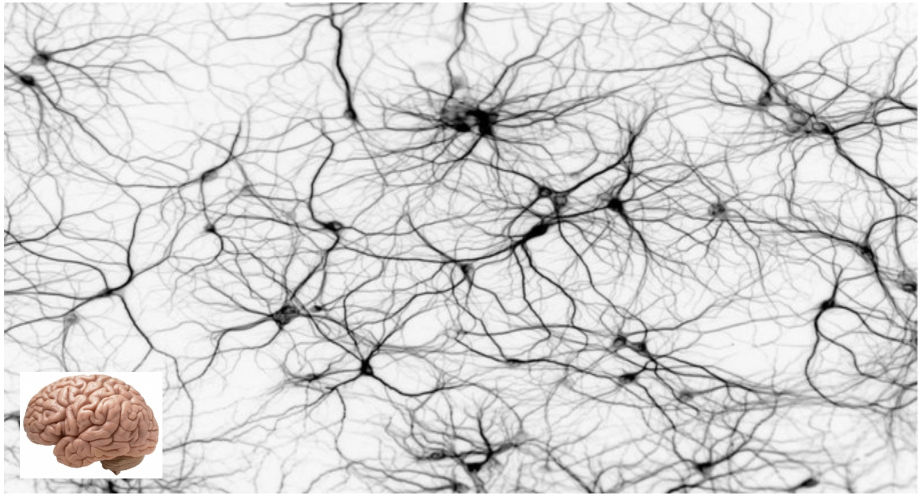
- Inspired by biological neural networks



Human Brain: 86B Neurons; 86,000B Synapses

Deep Learning ≡ DNN

- Inspired by biological neural networks

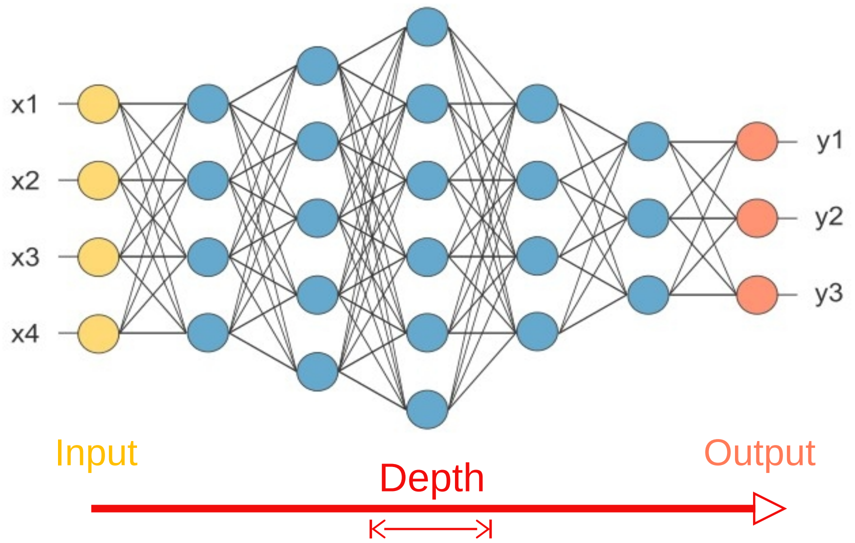


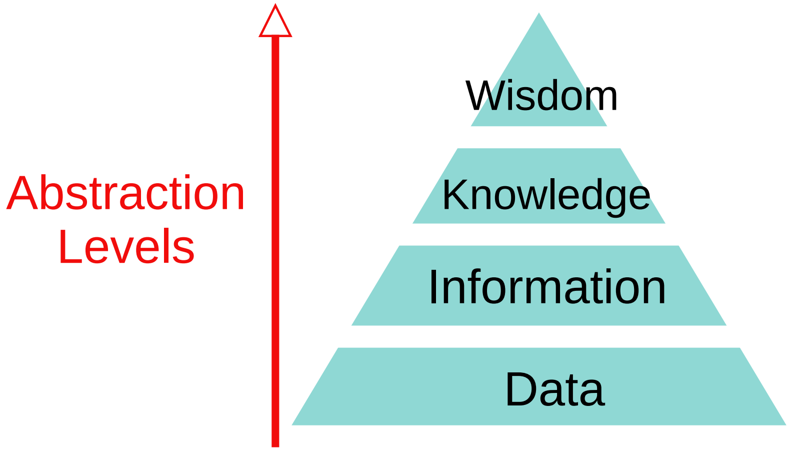
Human Brain: 86B Neurons; 86,000B Synapses

Airplanes have wing but do not flap!

DNNs vs Machine Learning (1)

- Depth → Abstraction → Better Features → Better Decisions

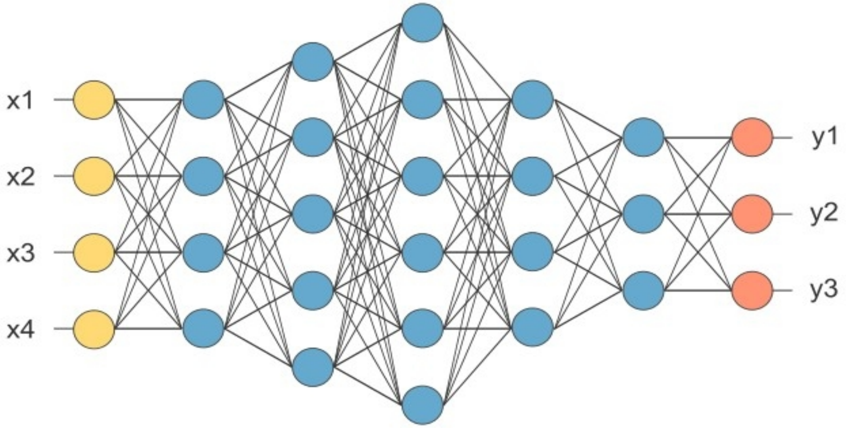




DNN: Deep Neural Network

DNNs vs Machine Learning (1)

- Depth → Abstraction → Better Features → Better Decisions



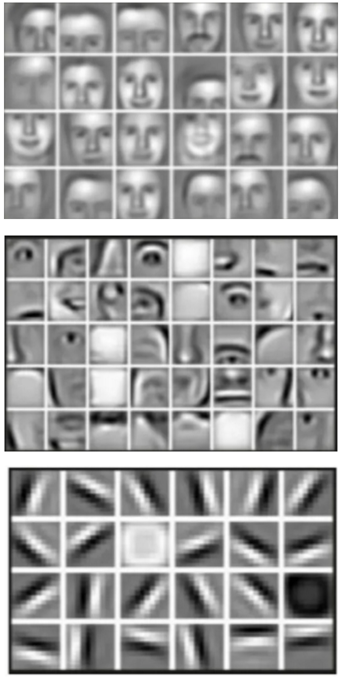
Input

Depth

Output

DNN: Deep Neural Network

Abstraction Levels

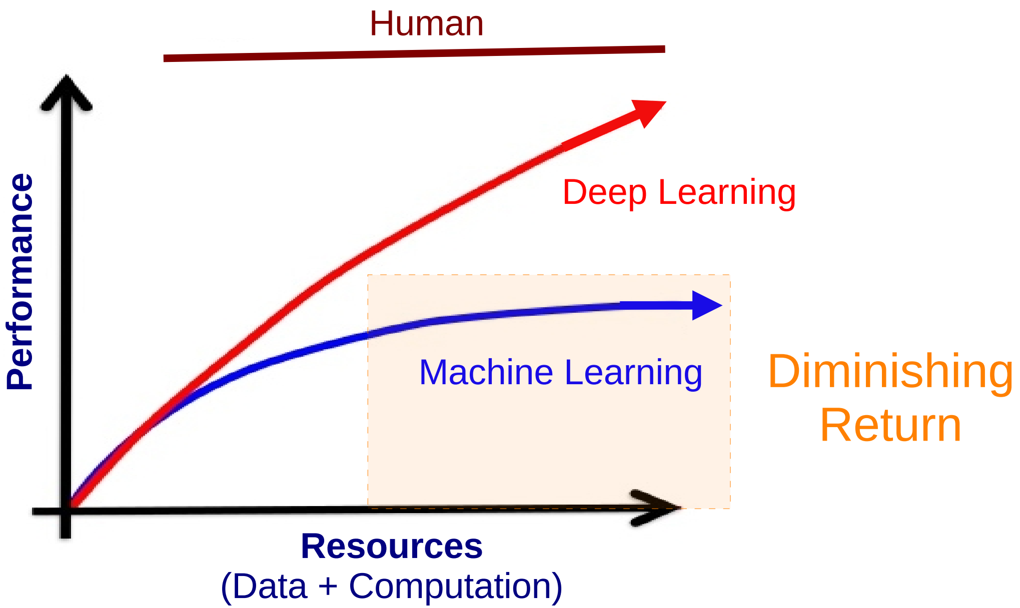


Face Recognition Task

Image adapted from:
Nicola Jones, Nature, 2014.

DNNs vs Machine Learning (2)

- Larger DNN + More Resources → Performance ↑



DNN: Deep Neural Network

Generative AI

- Powered by Deep Generative Models

- Can generate new content ...
  - Text → Text (GPT-4, 2023)
  - Text → Image (DALL.E 3, 2023)
  - Text → Video (Sora, 2024)
  - Text+Image → Text (GPT-4o, 2024)
  - Text → Speech (VALL-E 2, 2024)
  - ...

Generative AI

- Powered by Deep Generative Models
- Can generate new content ...
  - Text → Text (GPT-4, 2023)
  - Text → Image (DALL.E 3, 2023)
  - Text → Video (Sora, 2024)
  - Text+Image → Text (GPT-4o, 2024)
  - Text → Speech (VALL-E 2, 2024)
  - ...

Prompt

OpenAI GPT-4

DALL·E

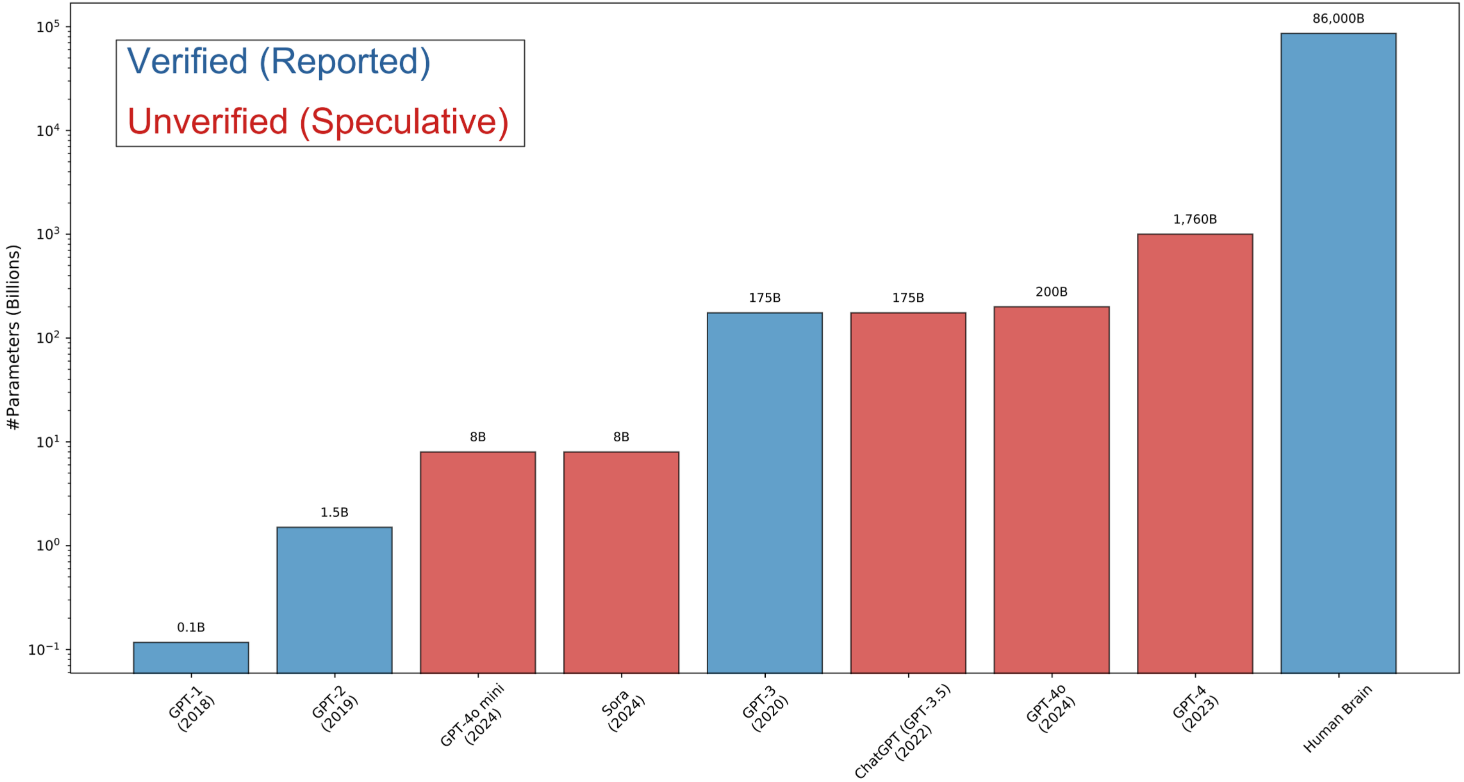
OpenAI Sora

OpenAI GPT-4o

Microsoft VALL-E

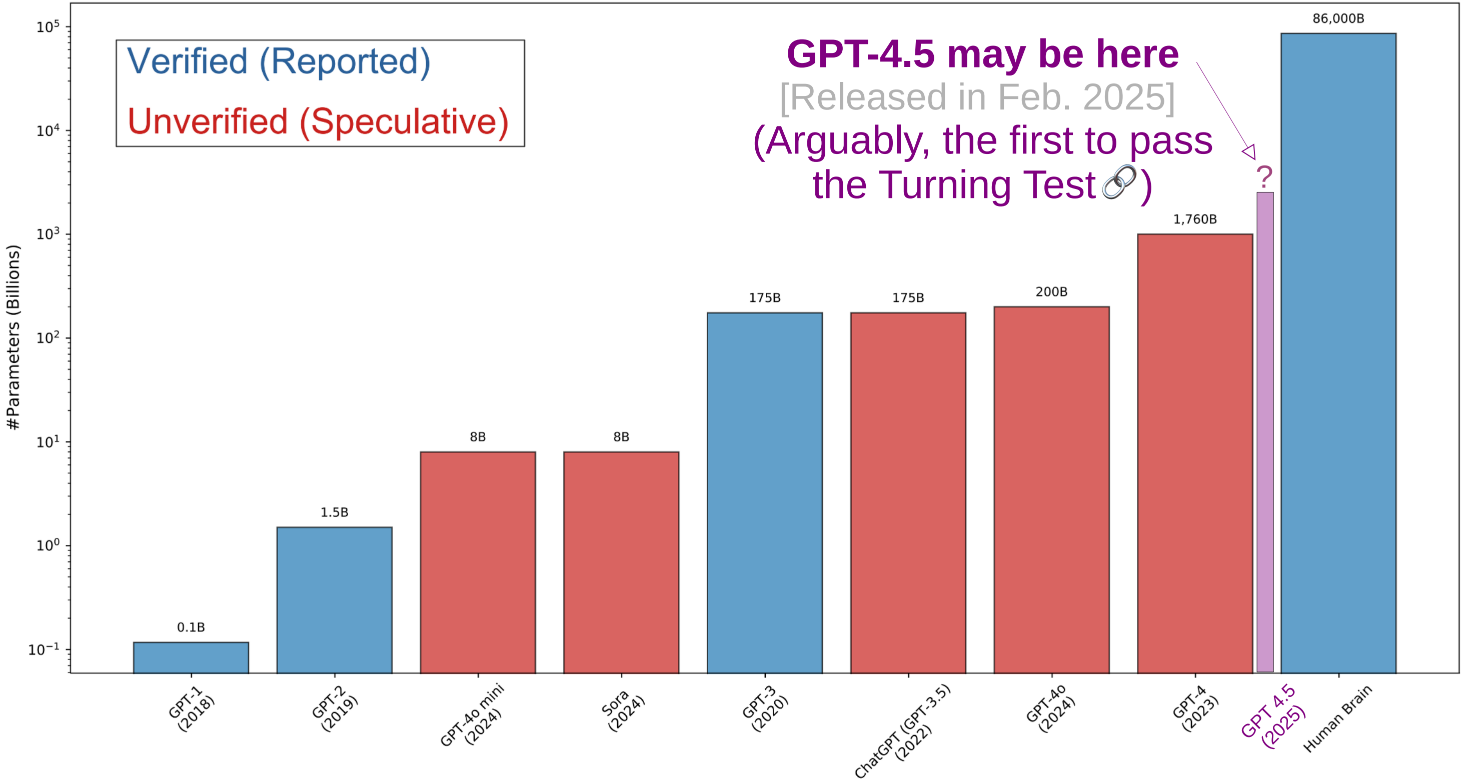
OpenAI’s Models vs Brain

Note the log scale



OpenAI’s Models vs Brain

Note the log scale



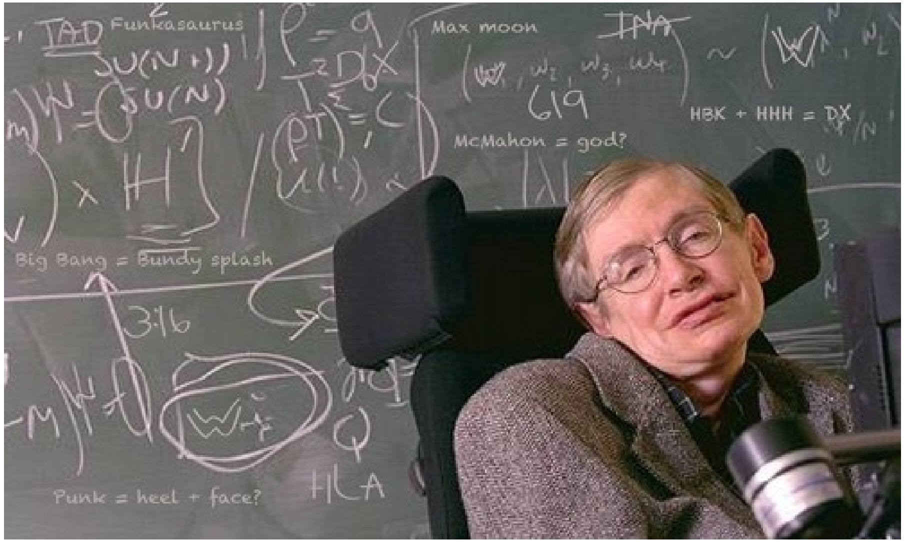
Large Language Models (LLMs)

- **Trained to** understand & generate original+coherent text

- **Capabilities**
  - Summarisation, Translation, Question Answering, Education, Chatbot, Virtual Assistance, Code Generation, Healthcare, …

- **Challenges**
  - Hallucination, Privacy, Security, Bias, Ethics, …

Rogue AI



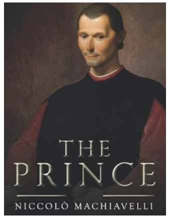
The development of full artificial intelligence could spell the end of the human race. [Source: BBC, 2014]

Stephen Hawking
(1942-2018)

Malicious Uses of AI

- Deepfake & Disinformation
- Cybersecurity Threats
- Targetted Manipulation
- Scam and Phishing
- Hacking
- ...

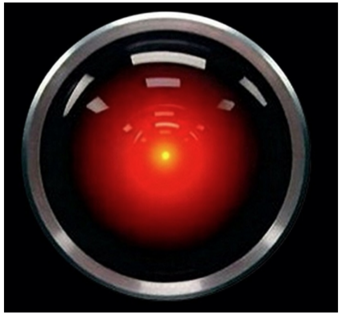
Rogue AI: Myth or Risk? (1)



- **Machiavellian AI**
  - *Manipulate, deceive, or pursue goals via strategic behaviour, without ethical constraints.*
  - *The ends justify the means!*
  - *Involves sophisticated reasoning … unavailable now … but …*

Machiavellian AI Example:
HAL 9000

***HAL**: I'm sorry Dave, I'm afraid I can't do that … This mission is too important for me to allow you to jeopardise it!* Link



- **Misson-driven**
  - Prioritise mission success over human life
- **Deceptive & Manipulative**
  - Hides critical information
- **Ends Justify Means**
  - Rational but unethical decisions

1968

Rogue AI: Myth or Risk? (2)

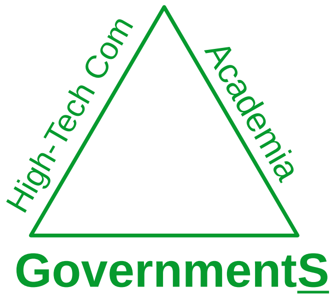
- **Intelligent ≠ Desire to Dominate**
  - Dominance is a human trait
- **Desire ≠ Capability**
  - Logistics/Autonomy/Resources are not granted by default
- **Self-awareness?**
  - Still speculative; being intelligent ≠ being conscious

Social Impact

- AI is driving 4th Industrial Revolution

- **Key Challenges**
  1. ⚡**Rapid**⚡Change → Adaptation → Job loss → Social unrest → ...
  2. Misuse by Bad Actors

- **Solutions**
  - Collaboration →
  - Reskilling, Education, AI Ethics, AI Crime Laws, …
  - Balancing Innovation with Responsibility



Reflection: Should we fear AI?

The danger of computers becoming like human is not as great as the danger of humans becoming like computers.

Konrad Zuse
(1910-1995)

That's it!

- Thank you!
- Q&A

Generated by ChatGPT (DALL·E 3, OpenAI)