CS 471: Introduction to AI

Module 1: Introduction to AI

Introduction

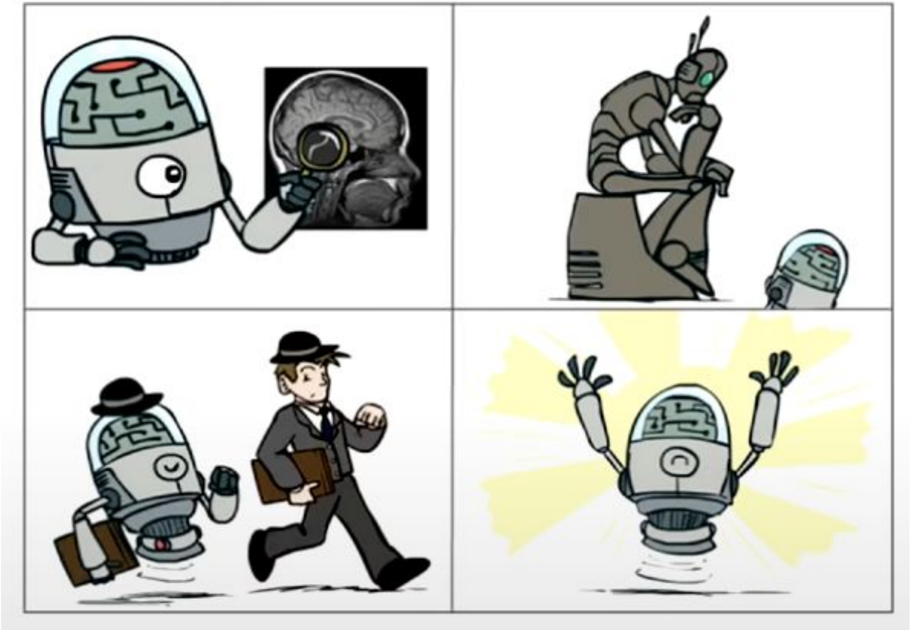
- The field of artificial intelligence (AI) is concerned with understanding and building intelligent entities: machines that can act effectively and safely in a wide variety of novel situations.
- AI applications range from general (learning, reasoning, and so on) to specific, such as:
  - playing chess,
  - proving mathematical theorems,
  - writing poetry,
  - driving a car, or
  - diagnosing diseases.

What is AI?

The science of making machines that:

Think like people

Think rationally



Act like people

Act rationally

Rational Agent

- An agent is something that acts
- A rational agent is one that acts so as to achieve the best outcome or, when there is uncertainty, the best expected outcome

AI has focused on the study and construction of agents that do the right thing.

Ultimately, we want agents that are provably beneficial to humans

Foundations of AI

Foundations of AI

Philosophy: Where does knowledge come from?

Mathematics: How do we reason with uncertain information?

Economics: How should we make decisions in accordance with our preferences?

Psychology: How do humans and animals think and act?

Computer engineering: How can we build an efficient computer?

Linguistics: How does language relate to thought?

Foundations of AI

NeuroScience

- Neuroscience is the study of the nervous system, particularly the brain.
- Although the exact way in which the brain enables thought is one of the great mysteries of science, the fact that it does enable thought has been appreciated for thousands of years.

History of AI

History of AI

John McCarthy - Father of AI who coined the term “Artificial Intelligence”

Turing Award winners:

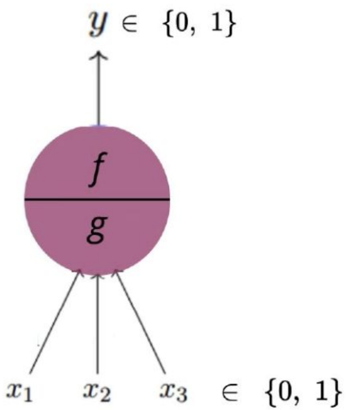
- Marvin Minsky (1969) and John McCarthy (1971) for defining the foundations of the field based on representation and reasoning;
- Ed Feigenbaum and Raj Reddy (1994) for developing expert systems that encode human knowledge to solve real-world problems;
- Judea Pearl (2011) for developing probabilistic reasoning techniques that deal with uncertainty in a principled manner; and
- Yoshua Bengio, Geoffrey Hinton, and Yann LeCun (2019) for making “deep learning” (multilayer neural networks) a critical part of modern computing.

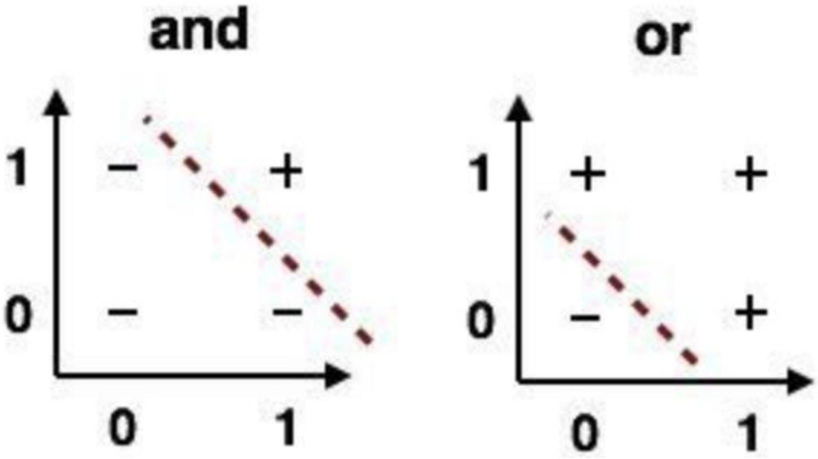
History of AI

- The Inception of AI (1943-1956) - MP neuron and first neural network computer
- Early enthusiasm, great expectations (1952-1969) - Games, puzzles, mathematics, IQ tests, perceptron
- A dose of reality (1966-1973) - intractability of AI methods, fundamental limitations
- Expert systems (1969-1986) - inferring molecular structure, diagnosing blood infections, AI Winter
- The return of neural networks (1986-present) - back-propagation was reinvented
- Probabilistic reasoning and machine learning (1987-present) - Probability rather than boolean logic, ML rather than hard coding, shared datasets
- Big data (2001-present) - availability of large datasets (ImageNet, IBM Watson system)
- Deep learning (2011-present) - exceeds human performance, takes advantage of hardware, data, and powerful algorithms

The Inception of AI (1943-1956)

The first work that is now recognized as AI was done by Warren McCulloch and Walter Pitts (1943).





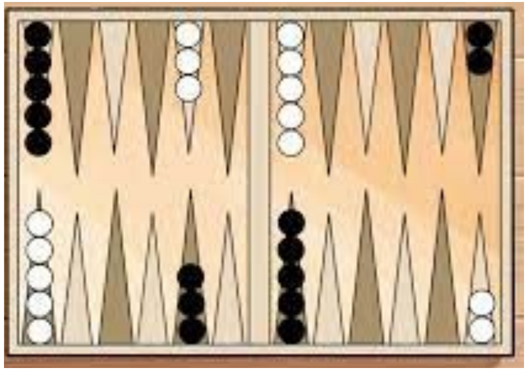
Two undergraduate students at Harvard built the first neural network computer in 1950

Early Enthusiasm, Great Expectations (1952-1969)

- Focused on tasks considered indicative of intelligence in humans, including games, puzzles, mathematics, and IQ tests.
- Herbert Gelernter (1959) constructed the Geometry Theorem Prover, which was able to prove theorems that many students of mathematics would find quite tricky.

Early Enthusiasm, Great Expectations (1952-1969)

- Samuel's programs disproved the idea that computers can do only what they are told to: his program quickly learned to play a better checkers game than its creator.
- Later systems: TD-GAMMON (Tesauro, 1992), the world's best backgammon players, and ALPHAGO (Silver et al., 2016), which shocked the world by defeating the human world champion at Go.



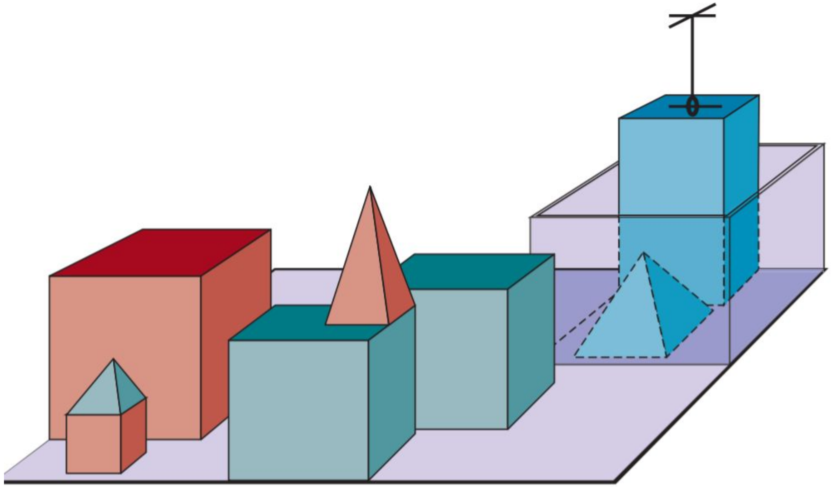
Early Enthusiasm, Great Expectations (1952-1969)

- James Slagle's SAINT program (1963) was able to solve **closed-form calculus integration problems** typical of first-year college courses.
- Tom Evans ANALOGY program (1968) solved **geometric analogy problems** that appear in IQ tests.
- Daniel Bobrow STUDENT program (1967) solved **algebra story problems**, such as the following:

  If the number of customers Tom gets is twice the square of 20 percent of the number of advertisements he runs, and the number of advertisements he runs is 45, what is the number of customers Tom gets?

Early Enthusiasm, Great Expectations (1952-1969)

- Another famous work is the blocks world, which consists of a set of solid blocks placed on a tabletop.
- A scene from the blocks world. SHRDLU has just completed the command “Find a block which is taller than the one you are holding and put it in the box.”



Person: Pick up a big red block.

Computer: OK.

Person: Grasp the pyramid.

Computer: I DON'T UNDERSTAND WHICH PYRAMID YOU MEAN.

Person (changing their mind): Find a block which is taller than the one you are holding and put it into the box.

Computer: BY "IT", I ASSUME YOU MEAN THE BLOCK WHICH IS TALLER THAN THE ONE I AM HOLDING.

Computer: OK.

Person: What does the box contain?

Computer: THE BLUE PYRAMID AND THE BLUE BLOCK.

Person: What is the pyramid supported by?

Computer: THE BOX.

Person: How many blocks are not in the box?

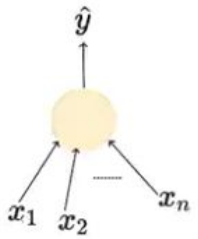
Computer: FOUR OF THEM.

Early Enthusiasm, Great Expectations (1952-1969)

Frank Rosenblatt (1962) called his networks as perceptrons

Difference between Warren McCulloch and Walter Pitts neuron, and perceptron

MP Neuron

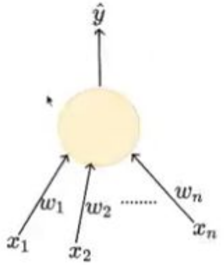


$\hat{y} = 1$ if $\sum_{i=1}^{n} x_i \geq b$

$\hat{y} = 0$ otherwise

- Boolean inputs
- Linear
- Inputs are not weighted
- Adjustable threshold

Perceptron



$\hat{y} = 1$ if $\sum_{i=1}^{n} w_i x_i \geq b$

$\hat{y} = 0$ otherwise

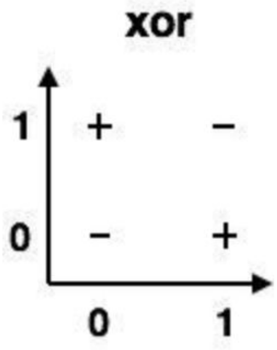
- Real inputs
- Linear
- Weights for each input
- Adjustable threshold

The perceptron convergence theorem (Block et al., 1962) says that the learning algorithm can adjust the connection strengths of a perceptron to match any input data.

A Dose of Reality (1966-1973)

- These early systems failed on more difficult problems.
- Two main reasons for this failure.

1. Lack of knowledge of the intractability of problems AI was attempting to solve: Most of the early problem-solving systems worked by trying out different combinations of steps until the solution was found. This strategy worked initially because microworlds contained very few objects and hence very few possible actions and very short solution sequences.
2. Fundamental limitations: A perceptron (a simple form of neural network) could not be trained to recognize when its two inputs were different, such as xor gate. Research funding for neural-net research soon dwindled to almost nothing.



Expert Systems (1969-1986)

- The DENDRAL program: Developed at Stanford to solve the problem of inferring molecular structure from the information provided by a mass spectrometer.
- Next major effort was the MYCIN system for diagnosing blood infections. With about 450 rules, MYCIN was able to perform as some experts, and considerably better than junior doctors.

Expert Systems (1969-1986)

- Overall, the AI industry boomed from a few million dollars in 1980 to billions of dollars in 1988, including hundreds of companies building expert systems, vision systems, robots, and software and hardware specialized for these purposes.
- None of these projects ever met its ambitious goals.
- Soon after that came a period called the “AI winter,” in which many companies fell by the wayside as they failed to deliver on extravagant promises.

The Return of Neural Networks (1986-present)

- Back-propagation learning algorithm was reinvented.
- Capable to learn from examples

Probabilistic Reasoning & Machine Learning (1987-present)

- This era incorporated probability rather than Boolean logic, machine learning rather than hand-coding.
- It became more common to show relevance to real-world applications rather than toy examples.
- Shared benchmark problem sets have been released:
  - UC Irvine repository for machine learning: https://archive.ics.uci.edu/ml/index.php
  - The MNIST data set for handwritten digit recognition,
  - ImageNet and COCO for image object recognition,
  - SQUAD for natural language question answering: https://rajpurkar.github.io/SQuAD-explorer/
  - WMT competition for machine translation. https://www.statmt.org/wmt14/translation-task.html

Big Data (2001-present)

- Creation of very large data sets: known as big data.
- Improvement in performance obtained from increasing the size of the data set outweighs any improvement that can be obtained from tweaking the algorithm.

Big Data (2001-present)

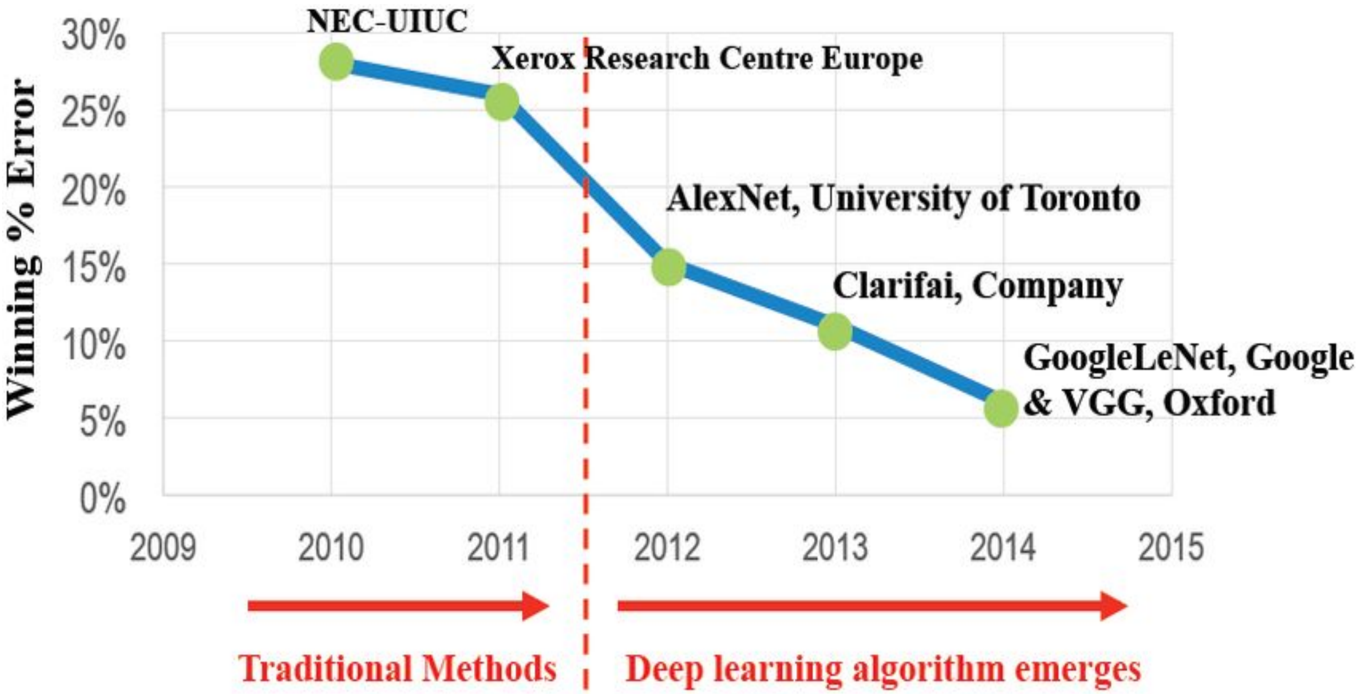
- To fill holes in photographs, Hays and Efros (2007) developed a method by blending in pixels from similar images; they found the technique worked poorly with a database of only thousands of images but crossed a threshold of quality with millions of images.
- The availability of tens of millions of images in the ImageNet database sparked a revolution in the field of computer vision.

Deep Learning (2011-present)

- The term deep learning refers to machine learning using multiple layers of simple, adjustable computing elements.
- Experiments were carried out with convolutional neural networks in 1970s, but they found some success in handwritten digit recognition in the 1990s (LeCun et al., 1995).
- It was not until 2011, however, that deep learning methods really took off.

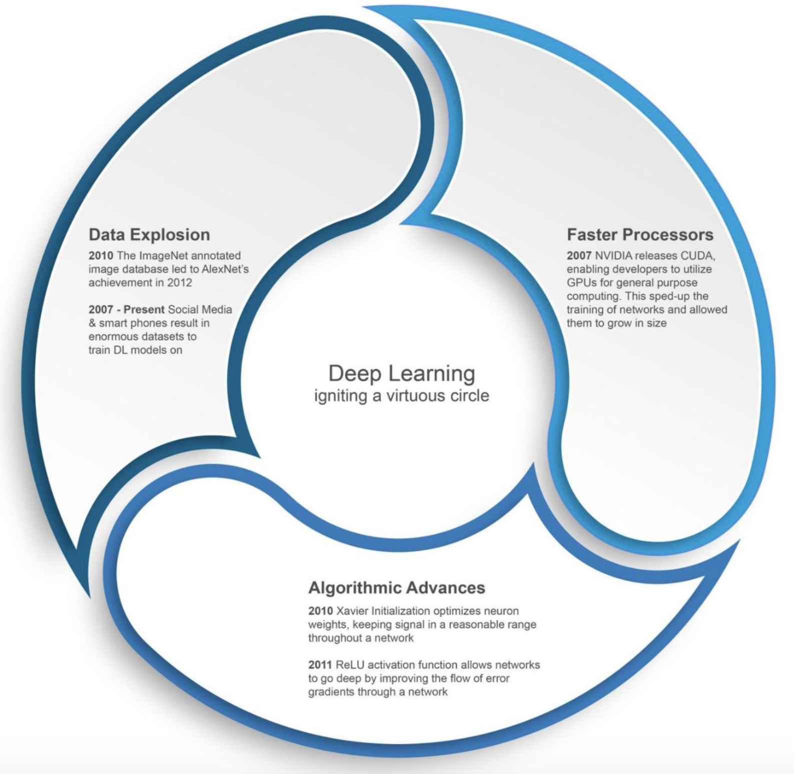
Deep Learning (2011-present)

In the 2012 ImageNet competition, which required classifying images into one of a thousand categories a deep learning system created in Geoffrey Hinton's group at the University of Toronto demonstrated a dramatic improvement over previous systems, which were based largely on handcrafted features.



Deep Learning (2011-present)

- Deep learning relies heavily on powerful hardware.
- Deep learning also depends on the availability of large amounts of training data, and on a few algorithmic tricks.



State-of-the-Art

State of the Art

- Stanford University’s One Hundred Year Study on AI (known as AI 100, https://ai100.stanford.edu/) consists of group of experts to study and anticipate how the effects of AI will ripple through every aspect of how people work, live and play.
- Some highlights:
    - Publications: AI papers increased
    - Sentiment: Articles with positive tone increased.
    - Students: Course enrollment increased.
    - Industry: AI startups in the U.S. increased
    - Vision: Exceeded human performance
    - Speed: Training time for the image recognition task dropped by a factor of 100 in just two years.
    - Language: Exceeded human-level performance.
    - Human benchmarks: Exceeded human-level performance in chess, Go, poker, Pac-Man, Jeopardy.

What can AI do Today?

- Machine translation
- Speech recognition
- Recommendations
- Game playing
- Image understanding =>
- Medicine
- Climate science

A person riding a motorcycle on a dirt road

These are just a few examples of artificial intelligence systems that exist today.

Risks and Benefits of AI

Risks and Benefits of AI

- Potential of AI and robotics is to free humanity from repetitive work and to dramatically increase the production of goods and services.
- We will incur risks from the misuse of AI, inadvertent or otherwise.
    - Lethal autonomous weapons
    - Surveillance: AI can be used to perform mass surveillance of individuals and detect activities of interest.
    - Biased decision making: Careless or deliberate misuse of machine learning algorithms for tasks such as evaluating loan applications can result in decisions that are biased by race, gender, or other protected categories.
    - Impact on employment:
        - Advances in technology have resulted in serious disruptions to employment

Summary

- History of AI has had cycles of success, misplaced optimism, and resulting cutbacks in enthusiasm and funding.
- AI field moved from Boolean logic to probabilistic reasoning, and from hand-crafted knowledge to machine learning from data.
- As AI systems find application in the real world, it has become necessary to consider a wide range of risks and ethical consequences.

THANK YOU!