Deep Learning Neural Networks

What they are, what they can do, and what they cannot do

James V Stone, University of Sheffield

Structure

A map of AI

What is a deep learning neural network?

What can neural networks do?

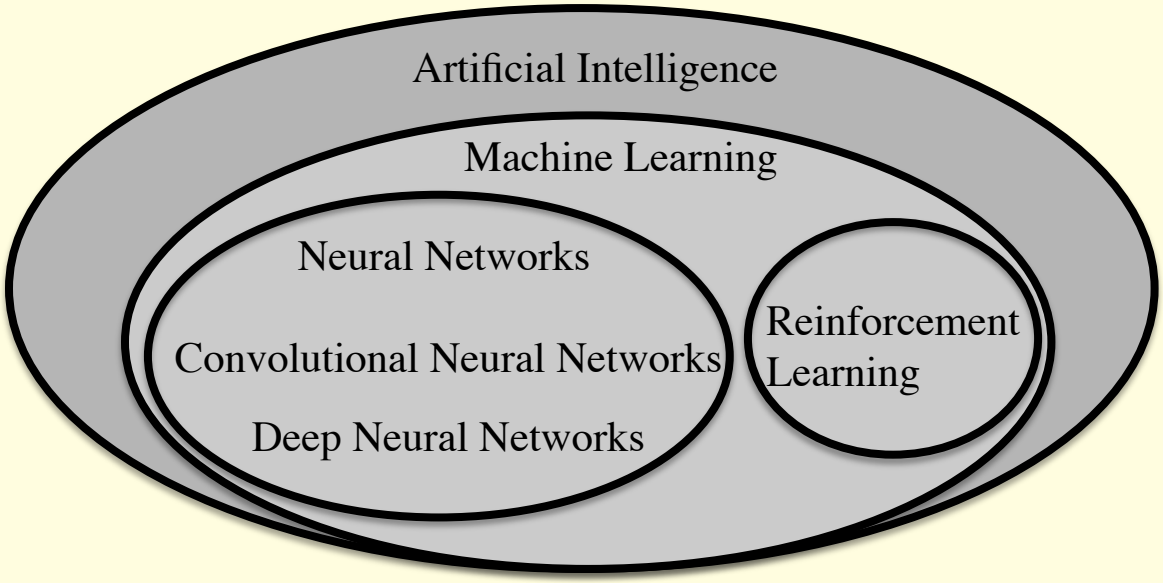
History of AI

- Before Artificial Neural Networks (1700-1940)
- Key Neural Network Developments (1940-present)

What can neural networks NOT do?

Conclusion

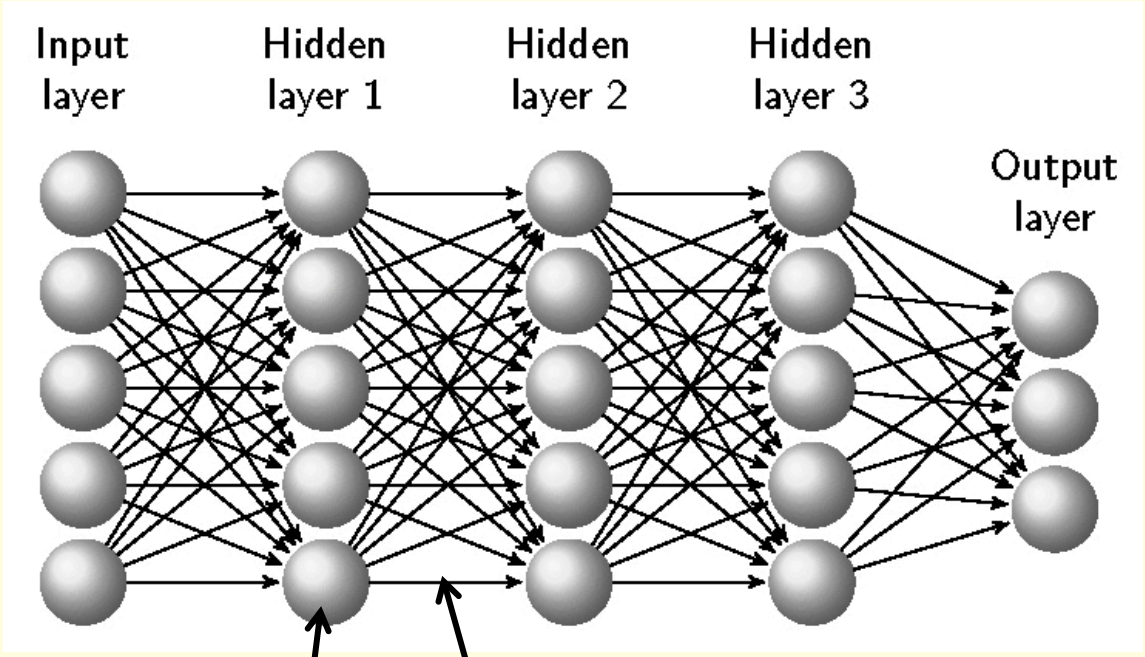
AI and all that ...



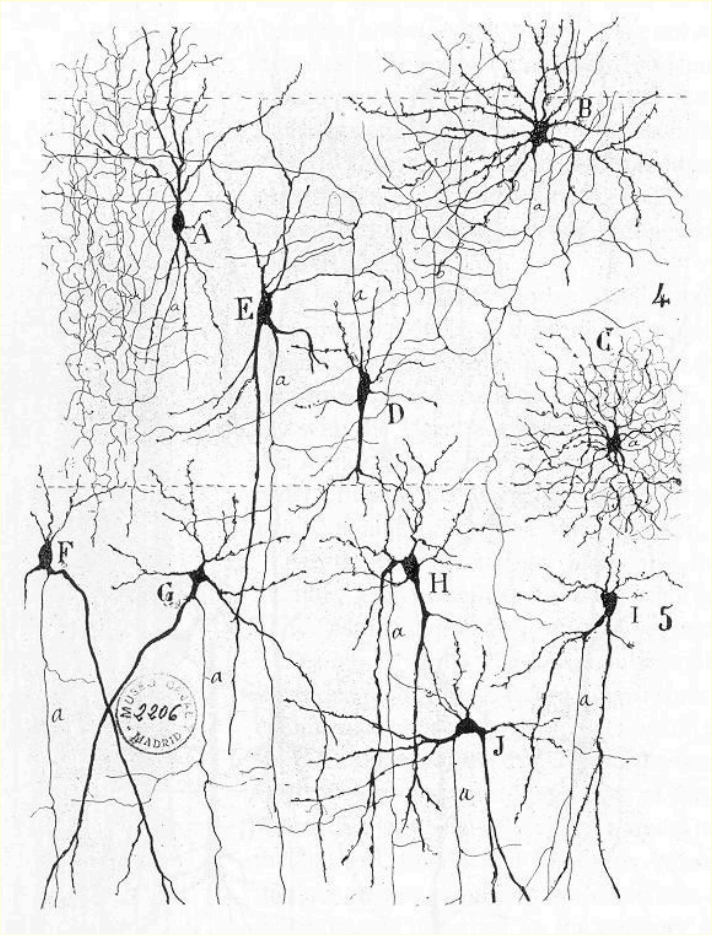
What is a deep learning neural network?

What is a deep learning neural network?

Deep learning network



Cajal's drawing of neurons, 1900

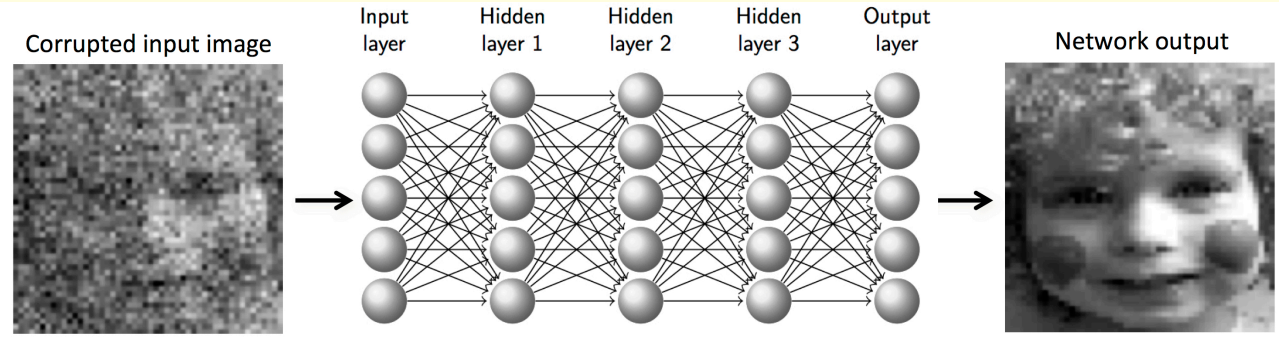


Three similarities to human memory

1) ***Content Addressable.*** Neural network memories are ***content addressable***, so recall is triggered by an image or a sound. In contrast, a computer memory can be accessed only if the specific location (address) of the required information is known.

2) ***Generalisation.*** Neural networks can ***generalise***. Recall can be triggered by an input image that is merely similar to a learned association.

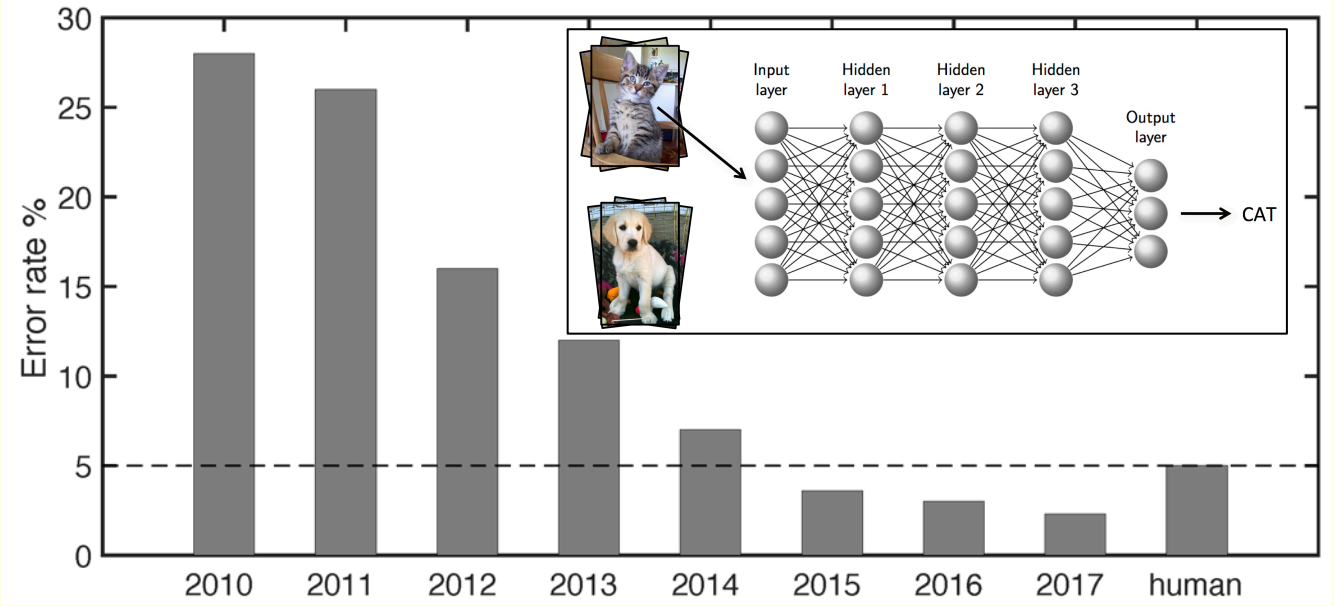
3) ***Graceful Degradation***. If a single weight or unit is destroyed, this does not remove a particular learned association; instead, it degrades all associations to some extent.



What can neural networks do?

What can deep neural networks do? Classifying Images

- The latest competition involves classifying about 1.5 million images into 1,000 object classes.
- The percentage error on the annual Large Scale Visual Recognition Challenge (ILSVRC) image classification competition has fallen dramatically since 2010.



Reproduced with permission from Wu and Gu (2015).

Recognising Numbers

Classifying images of hand-written numbers.

Face Recognition

In 2015, a deep convolutional neural network called FaceNet was trained on 200 million face images, and achieved an accuracy of 99.63%, which was a record at the time.
Schroff et al 2015.

What can deep neural networks do?
Synthetic celebrity faces

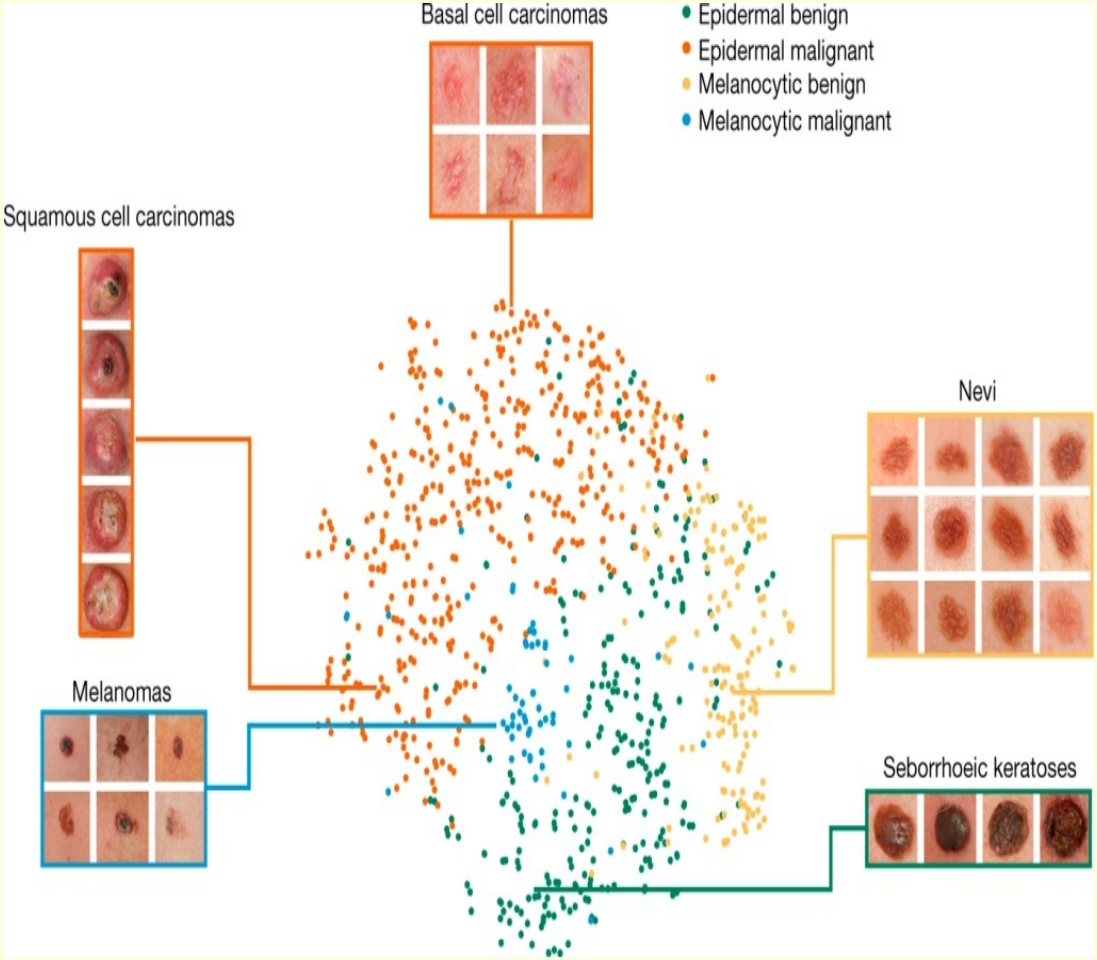
These people do not exist

Karras, 2018

Deepfakes

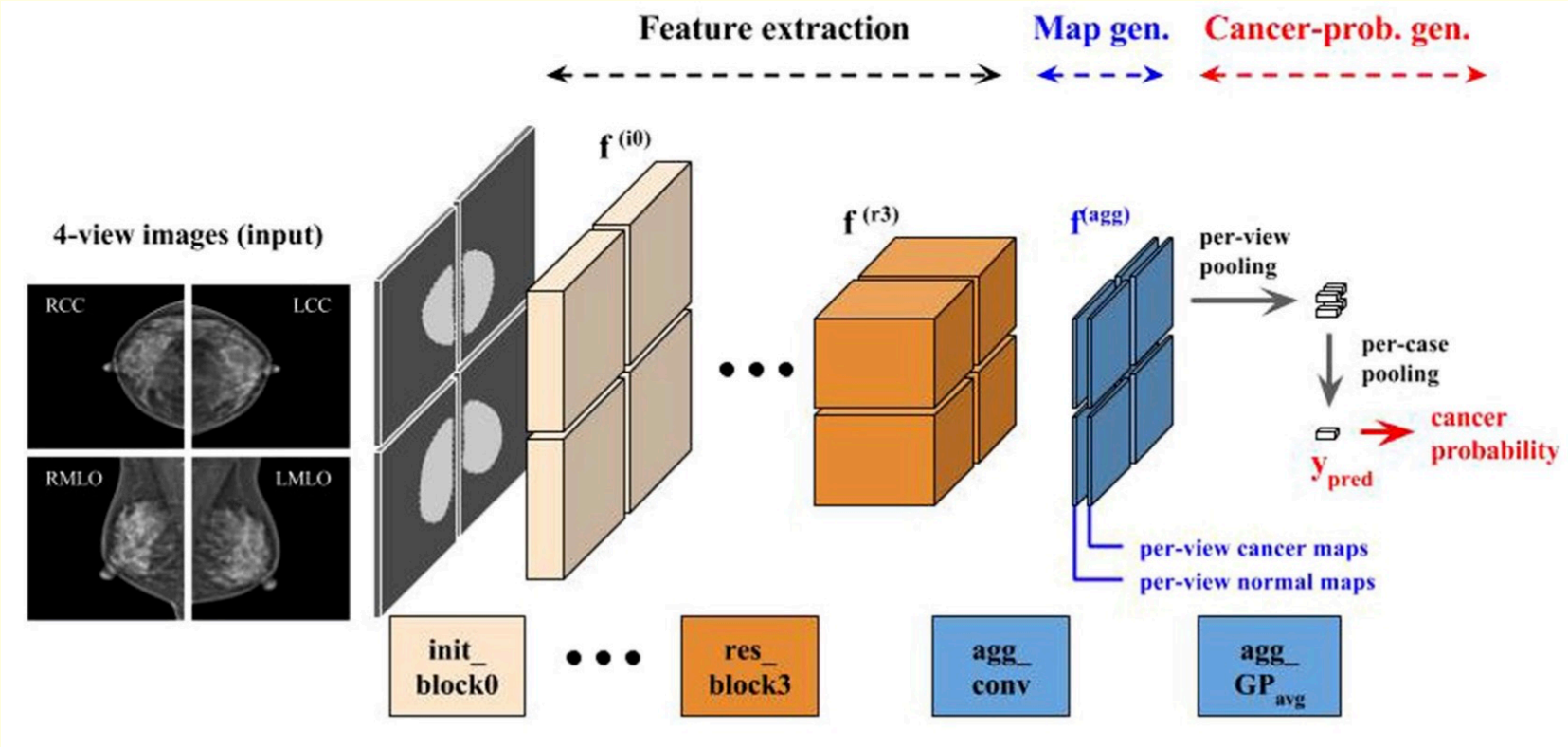
- https://www.youtube.com/watch?v=cQ54GDm1eL0
- Obama Deepfake

What can deep neural networks do?
Medical diagnosis



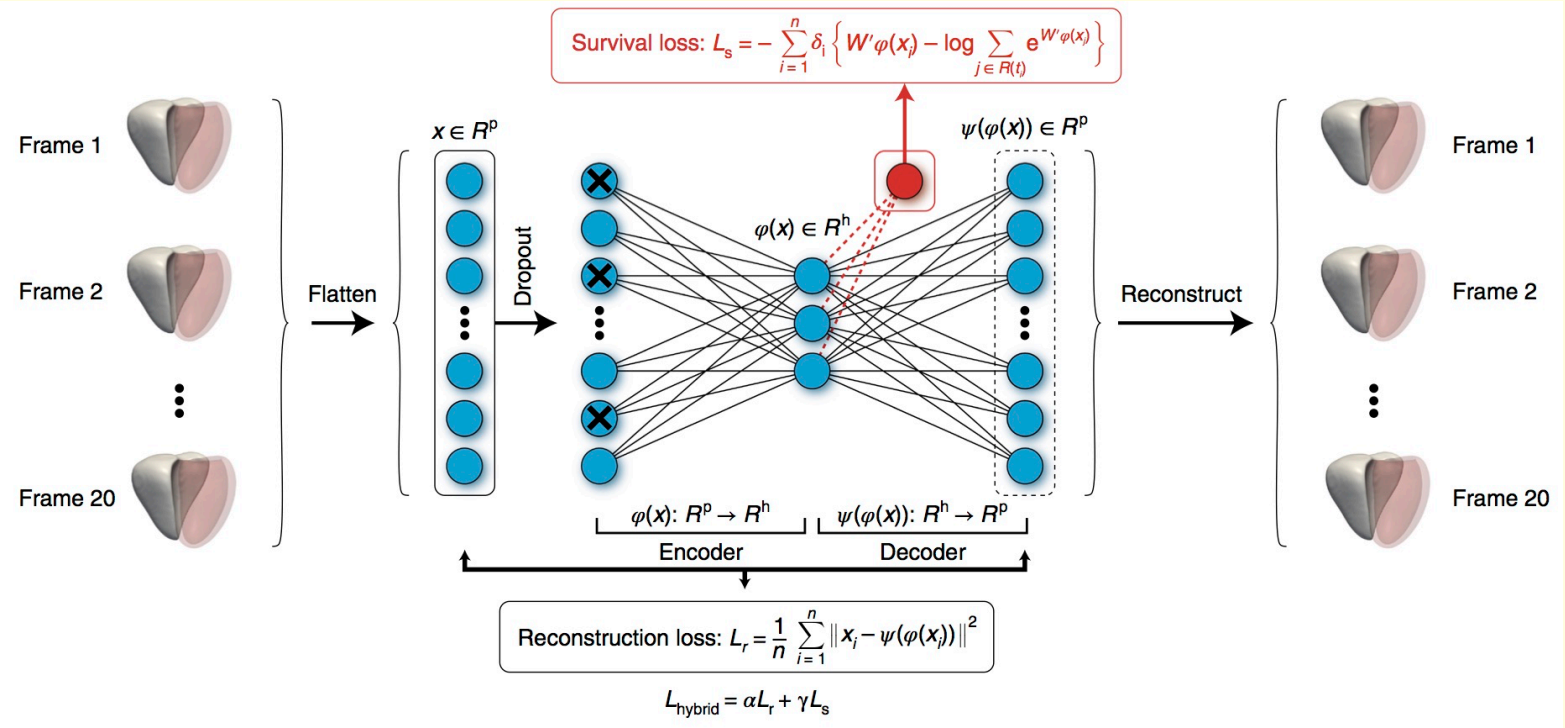
The Convolutional Neural Network's representation of four important disease classes of melanoma (skin cancer). 2017

What can deep neural networks do?
Medical diagnosis



Applying Data-driven Imaging Biomarker in Mammography for Breast Cancer Screening: Preliminary Study
Eun-Kyung Kim Nature, 2017.
AUC = 0.906 (AUC has range 0-1, and increases with accuracy).

What can deep neural networks do?
Medical diagnosis



Used a variational autoencoder to improve survival prediction based on motion of heart.
Ghalib et al 2019.

In vitro fertilisation (IVF)

- In vitro fertilisation (IVF) has a relatively low success rate, so anything that might improve matters is to be welcomed.
- Using time-lapse videos of over ten thousand developing embryos, a deep learning system predicted the development of a heart with an accuracy of 0.98 (AUC), compared to an estimated accuracy from embryologists of 0.74.
- Tran et al 2019.

Antibiotic Discovery

Tests showed that the drug wiped out a range of antibiotic-resistant strains of bacteria, including two of the three high-priority pathogens that the World Health Organization ranks as “critical” for new antibiotics to target.

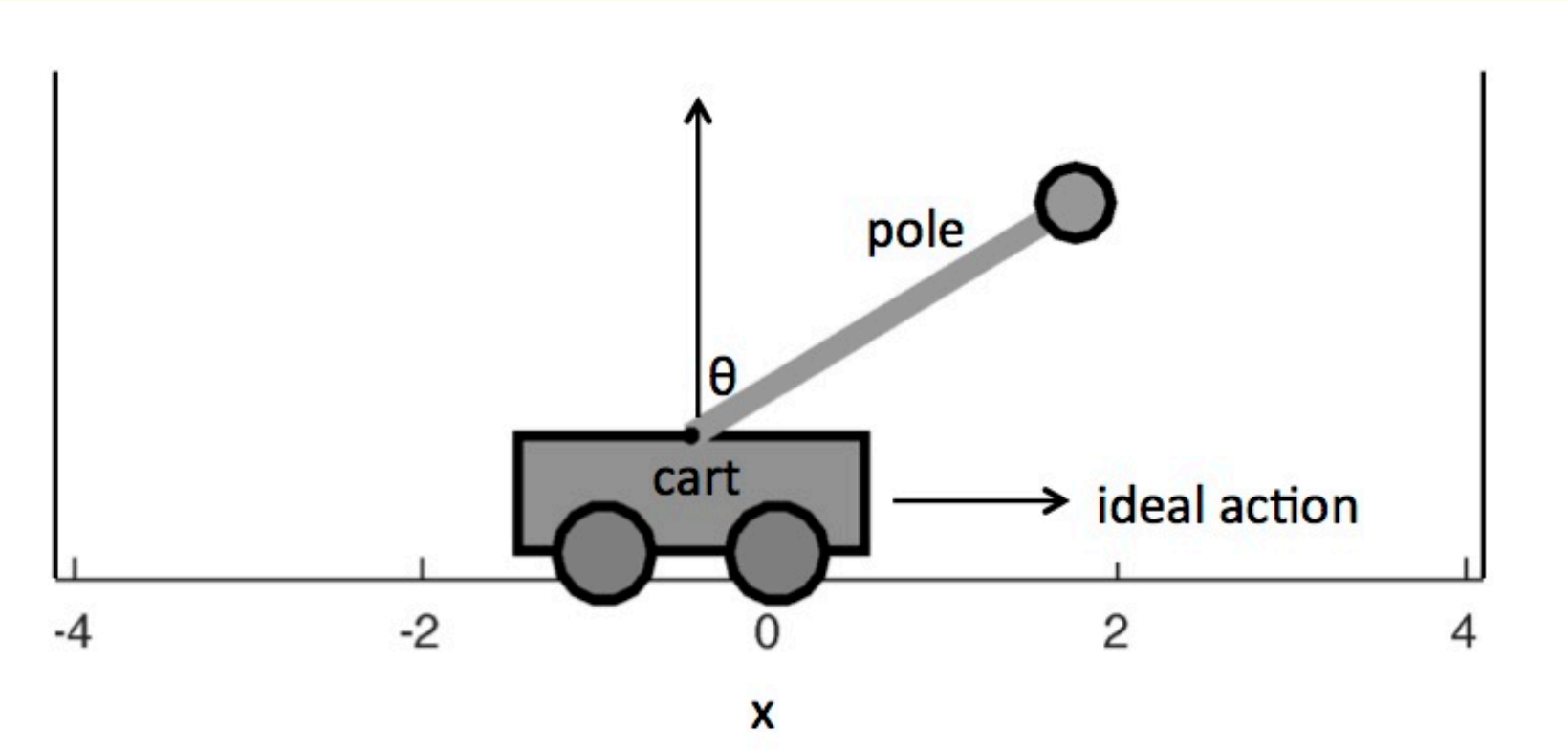
Jonathan M. Stokes et al, Feb 2020.

Quoted from Guardian 20/2/2020.

But ...

- As of February 2020, fifty algorithms had been approved by the USA Food and Drug Administration (FDA).
- However, FDA approval is not always based on the gold standard for medical treatment, which is the *randomised controlled trial* (RCT).
- Indeed, less than ten of the fifty FDA approved applications have been tested using RCT, and only twenty have even been tested in a clinical environment.

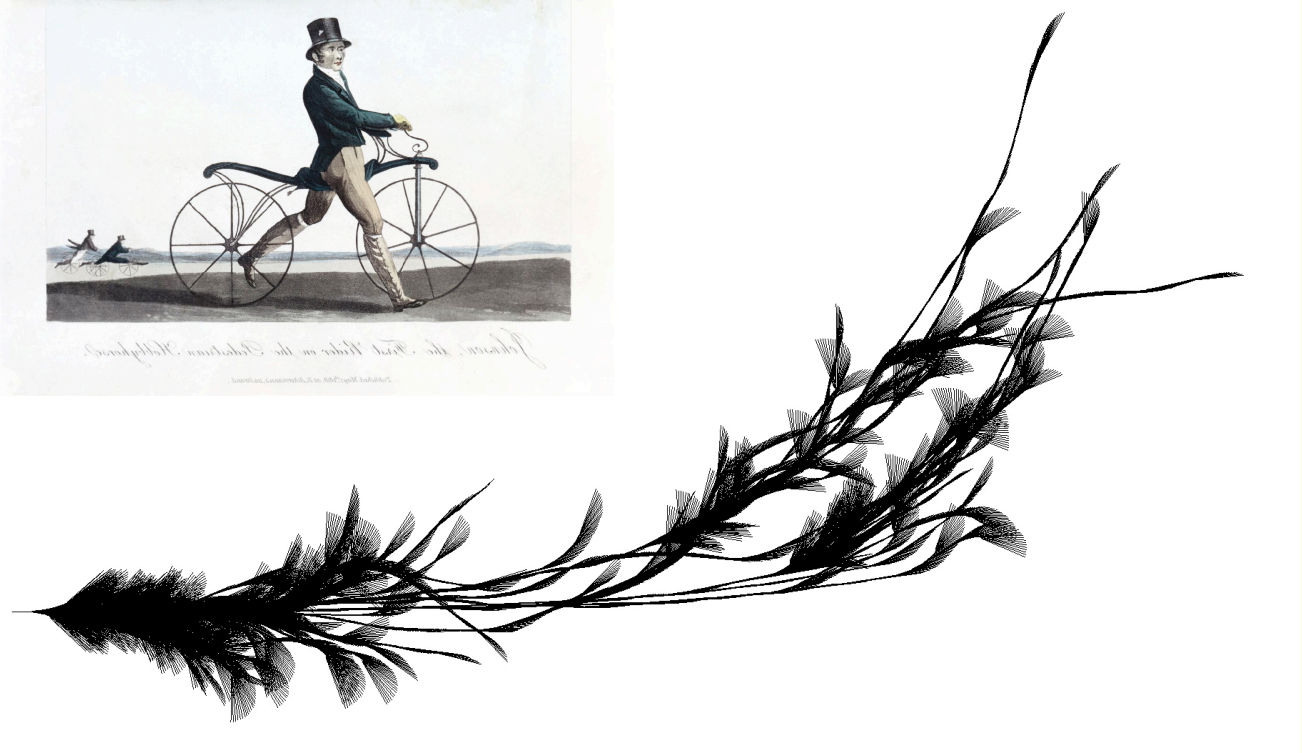
What can deep neural networks do?
Balancing a pole



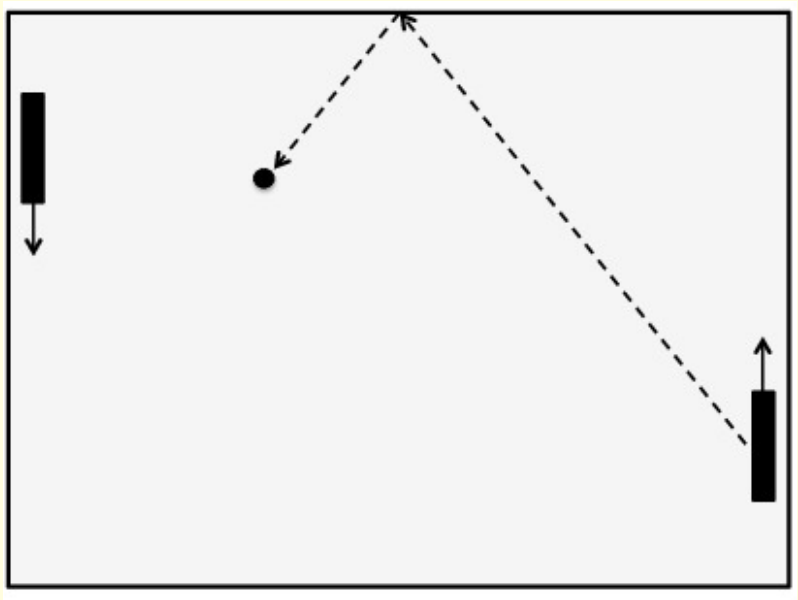
Sutton and Barto 1998-present

What can deep neural networks do? Cycling

View from above of cycle tracks. Uses RL. Randlov et al 1998

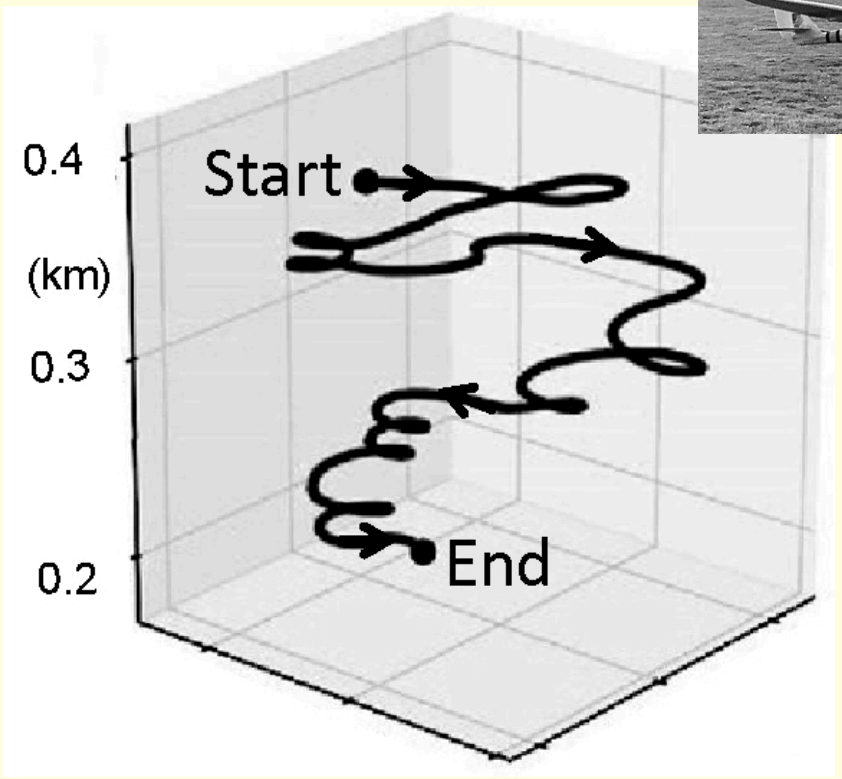


Atari games like Pong

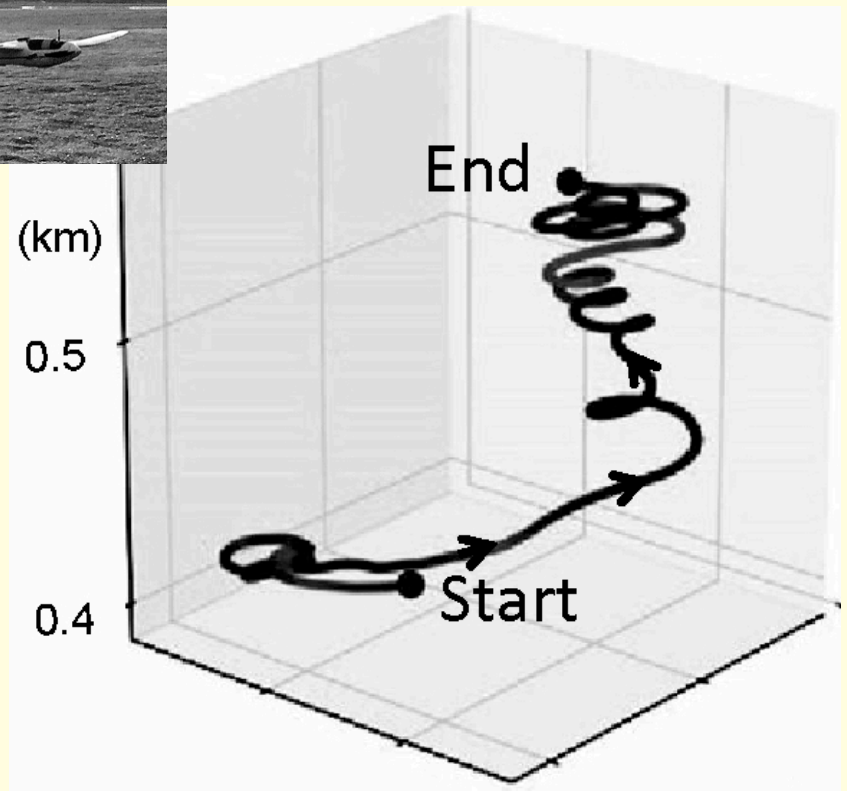


Atari games learned in from screen data.
2013: Mnih et al (2013).

What can deep neural networks do?
Flying



Before learning



After learning

Reddy et al 2016/18

What can deep neural networks do?
Go and Chess

Lee Sedol

- 2016: AlphaGo defeated Go grandmaster Lee Sedol 4 games to 1.

- 2017: AlphaGo (2.0) beat world champion, Ke Jie.
- 2017: AlphaGo Zero beat AlphaGo 100 games to 0.
- 2017: AlphaZero beat AlphaGo Zero.

- 2018: AlphaZero learned chess, shogi (Japanese chess), and Go, beating a world-champion program in each case.

Generating Captions

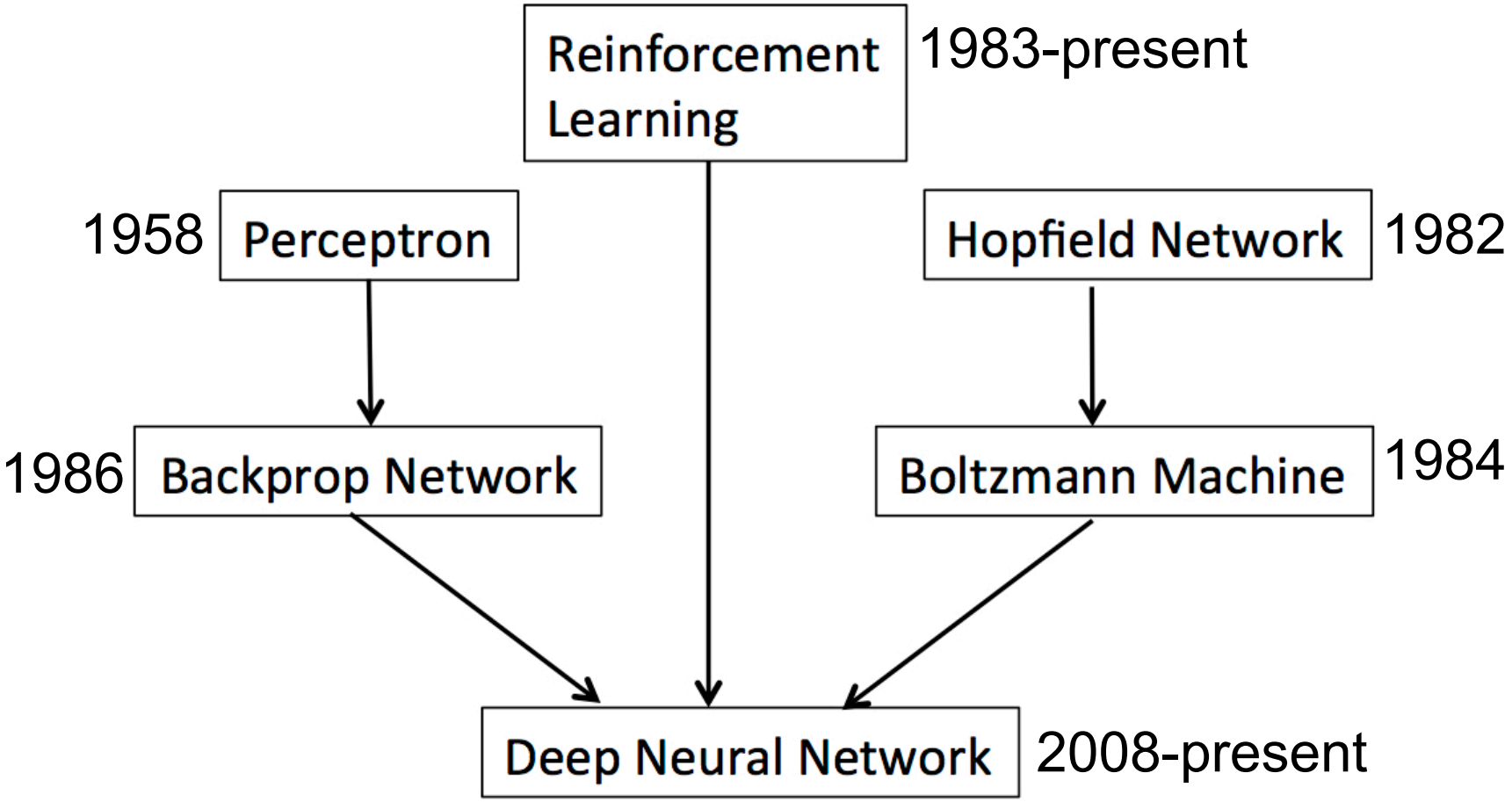
A basketball player catches the ball .

A climber sits on a rock

Ghosh, (2020)

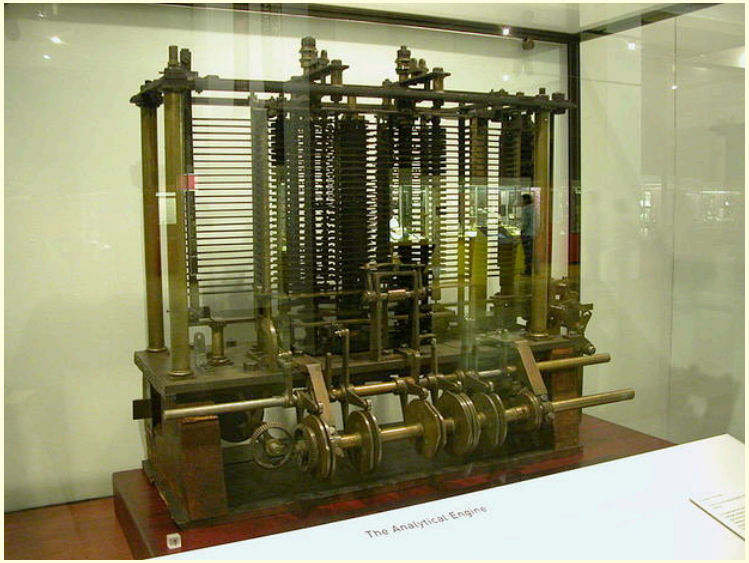
History of AI

Neural Networks History: 1983-present



Before Artificial Neural Networks (1/2)

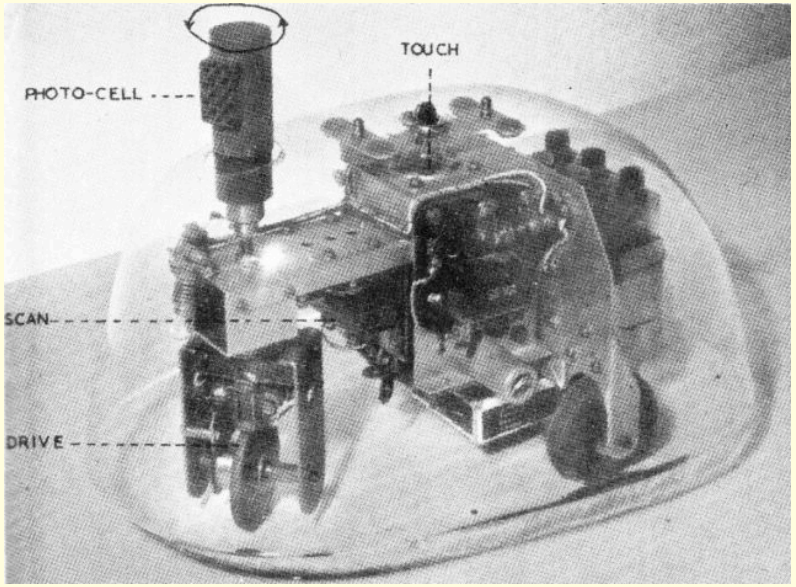
Pierre Jaquet-Droz, The Writer, 1770



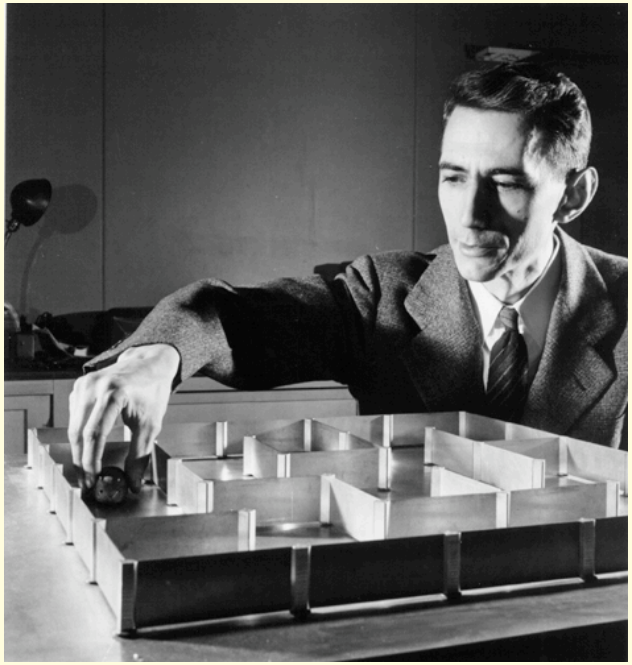
Ada Lovelace and Charles Babbage's Analytical Engine, 1842

Before Artificial Neural Networks (2/2)

Gray Walter's Turtle 1948



Claude Shannon's
Theseus Mouse, 1950

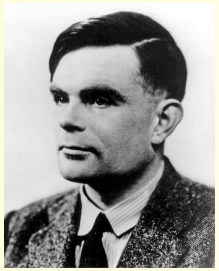


Key Developments: 1/4

1943: McCulloch and Pitts. "A logical calculus of the ideas immanent in nervous activity”

1949: Donald Hebb.
“The Organization of Behavior”

1949: Claude Shannon.
"Programming a Computer for Playing Chess”.

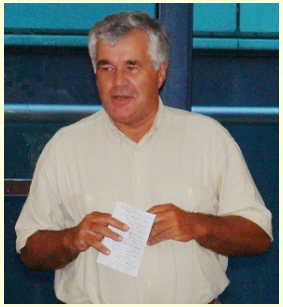


1950: Alan Turing.
“Computing Machinery and Intelligence”.

Key Developments: 2/4

1958: Frank Rosenblatt.

"The perceptron: A probabilistic model for information storage and organization in the brain."



1970: Longuet-Higgins, Willshaw, and Buneman.

"Theories of associative recall".

1972: T Kohonen.

"Correlation Matrix Memories".

1982: John Hopfield.

"Neural networks and physical systems with emergent collective computational abilities".

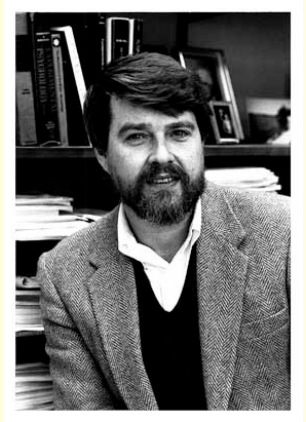
Key Developments: 3/4

1983: Barto, Sutton and Anderson.

"Neuronlike adaptive elements that can solve difficult learning control problems".

1984: Hinton, Sejnowski and Ackley.

"Boltzmann machines: Constraint satisfaction networks that learn".



1986: Rumelhart, Hinton and Williams.

"Learning representations by back-propagating errors".

Key Developments: 4/4

1989: LeCun, Boser, Denker, Henderson, Hubbard, and Jackel.

"Backpropagation applied to handwritten ZIP code recognition".

1995: G Tesauro. (backgammon)

"Temporal difference learning and TD-Gammon".

2012: Krizhevsky, Sutskever and Hinton. (AlexNet)

"Imagenet classification with deep convolutional neural networks".

2016: AlphaGo

"Mastering the game of Go with Deep Neural Networks & Tree Search", Silver, Huang, et al. Nature 2016

defeated Go grandmaster Lee Sedol. (see below)

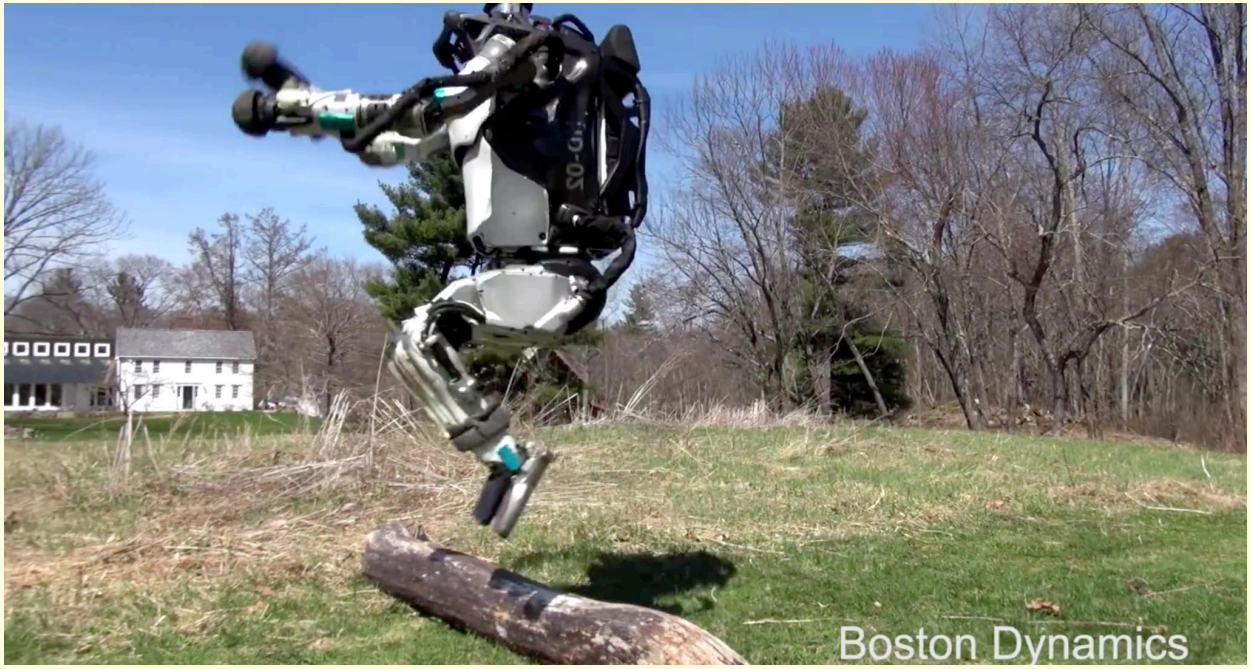
What can deep neural networks NOT do?

Definition of AI:
“AI is what computers cannot do yet”

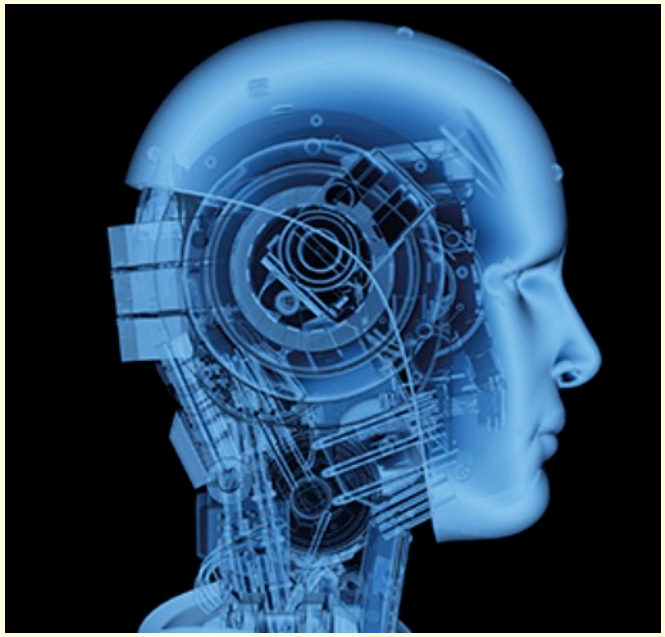
What can deep neural networks NOT do?
Artificial Intelligence (yet)

- washing up
- walk on rough ground
- fix a car
- drive a car
- put a t-shirt on
- clear snow
- build a shed
- IKEA
- take your pick

Boston dynamics robots do NOT use neural networks



What can deep neural networks NOT do?
Artificial Intelligence (yet)



AI in the press

```
#!/usr/bin/env python
import sys
import os
import simpleknn
from bigfile import BigFile

if __name__ == "__main__":
    trainCollection = 'toydata'
    nimages = 2
    feature = 'f1'
    dim = 3

    testCollection = trainCollection
    testset = testCollection
```

AI in the computer

Interpretability/Opacity

“Let us pretend that there was a machine, which was constructed in such a way as to give rise to thinking, sensing, and having perceptions. You could imagine it expanded in size ..., so that you could go inside it, like going into a mill. On this assumption, your tour inside it would show you the working parts pushing each other, but never anything which would explain a perception.”

Leibniz, 1714.

In Conclusion: Can a machine think?

Before Orville and Wilbur Wright flew the first aeroplane in 1903, skeptics declared that a machine could never fly like a bird. Today, many of us are like those skeptics, doubting that a machine could ever achieve human levels of intelligence.

But *birds and brains are physical devices, and they both must obey the same laws of physics.*

In other words, *a bird is a flying machine that happens to be made of organic matter, and a brain is a computational machine that happens to be made of neurons*.

It therefore seems obvious, and even *inevitable*, that a machine can fly even if it is not made of organic matter, and that a computational machine can be intelligent even if it is not made of neurons.

Q. Can a machine think?

A. Take a look in the mirror.

Recommended Resources

Geoffrey Hinton and Yann LeCun, The Turing Lecture 2019: https://www.youtube.com/watch?v=VsnQf7exv5I

Comment: *An overview from key researchers.*

Nielsen (2015), Neural Networks and Deep Learning is a free online book.
http://neuralnetworksanddeeplearning.com/

Comment: *A little dated, but still makes a fine starting point.*

Stone (2019), Artificial Intelligence Engines: A Tutorial Introduction to Deep Learning.

Comment: !

Thank you

THE END

Superhuman AI for multiplayer poker

Noam Brown[1,2]* and Tuomas Sandholm[1,3,4,5]*

In recent years there have been great strides in artificial intelligence (AI), with games often serving as challenge problems, benchmarks, and milestones for progress. Poker has served for decades as such a challenge problem. Past successes in such benchmarks, including poker, have been limited to two-player games. However, poker in particular is traditionally played with more than two players. Multiplayer games present fundamental additional issues beyond those in two-player games, and multiplayer poker is a recognized AI milestone. In this paper we present Pluribus, an AI that we show is stronger than top human professionals in six-player no-limit Texas hold'em poker, the most popular form of poker played by humans.

Science, August 2019. Did NOT neural networks ...

What can deep neural networks do?
Image Inpainting

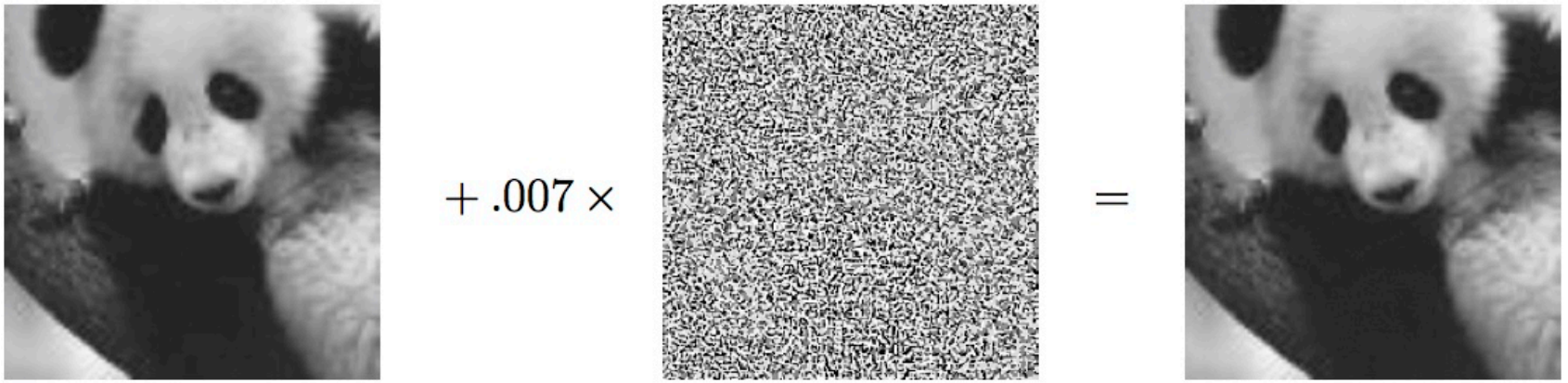
Before

During

After

by NVIDIA

What can deep neural networks NOT do?
Robust object recognition



Classified as
panda

Adversarial
noise

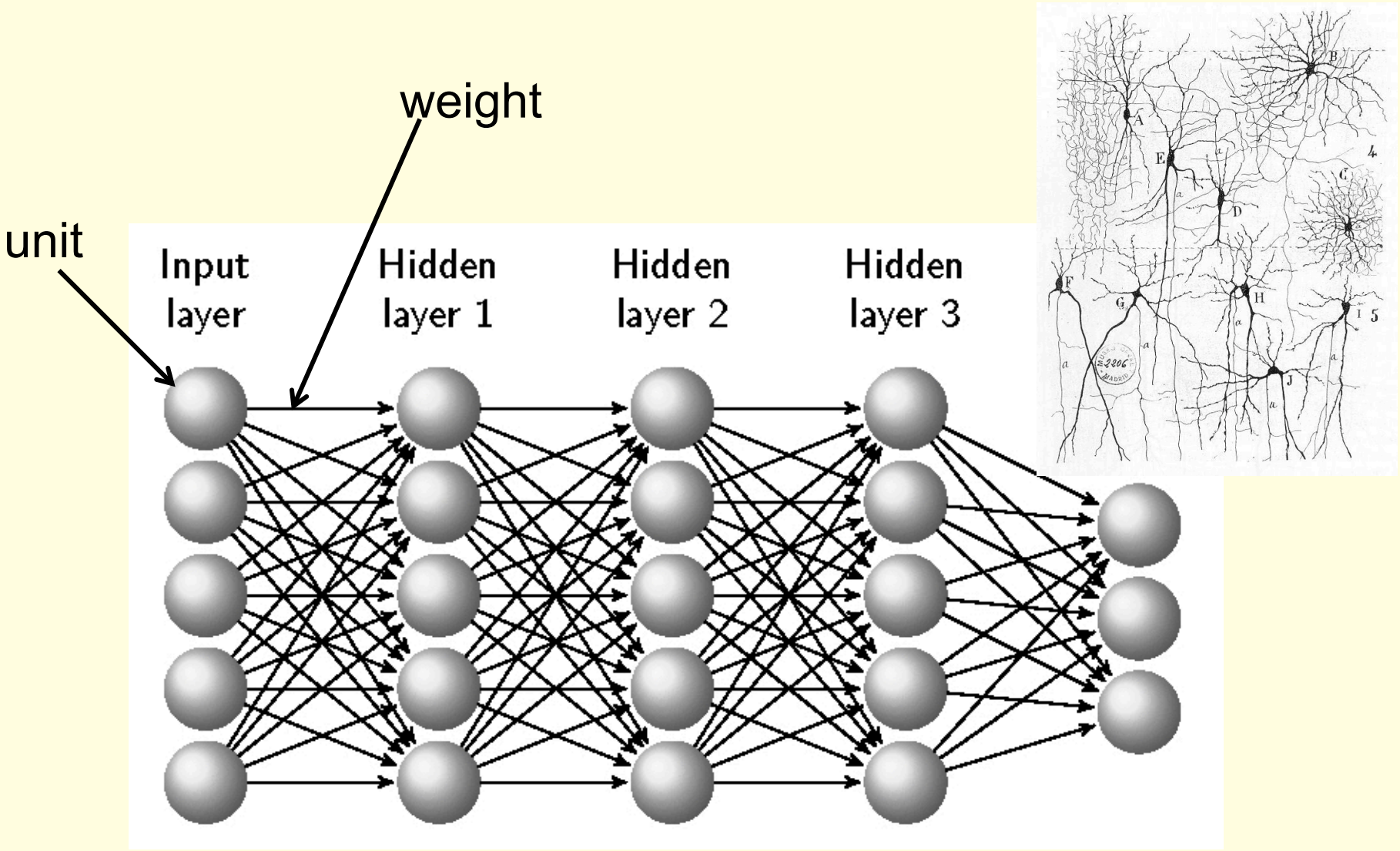
Classified as
gibbon

Goodfellow et al 2014

The Turing Day

- The workshop will be mostly lectures followed by a lab session.
- 10:00-11:00 Introduction: Deep Learning and AI: What it is, what it can, and cannot do. JVS
- 11:00-12:00 Overview: From linear networks to convolutional networks. SJE
- 12:00-13:00 Lunch
- 13:00-14:00 Deep Learning using Gradient Descent: What it is, and how it can fail. Backprop and overfittng and vanishing gradients. JVS
- 14:00-15:00 Reinforcement Learning. LDC
- 15:15-17:00 Using Python for networks. Lab session with all three instructors.

What is a deep learning neural network?



Spare pictures

- Object recognition
- Chess etc
- Flying
- Medical diagnosis

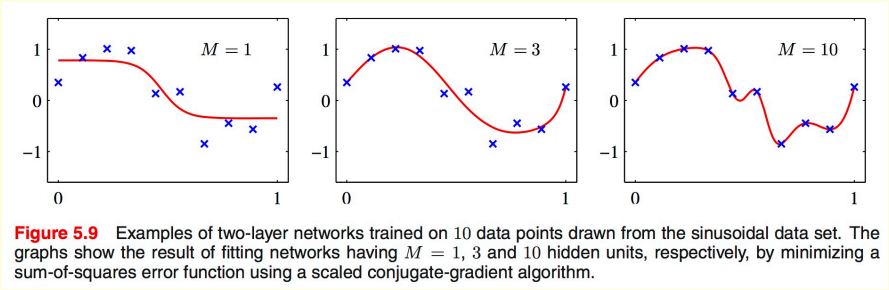
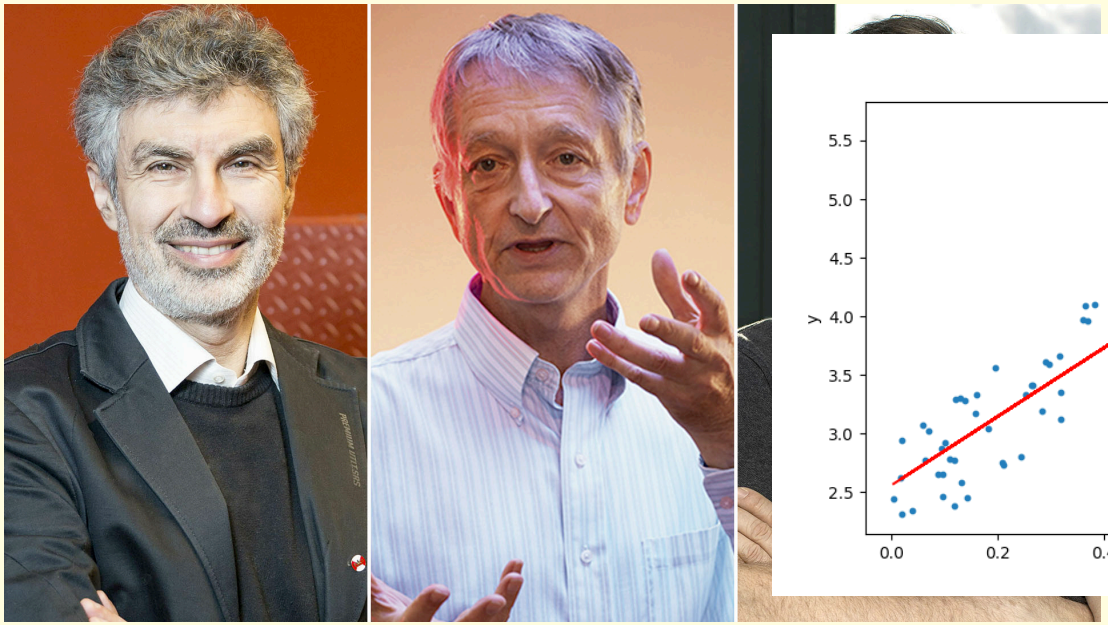
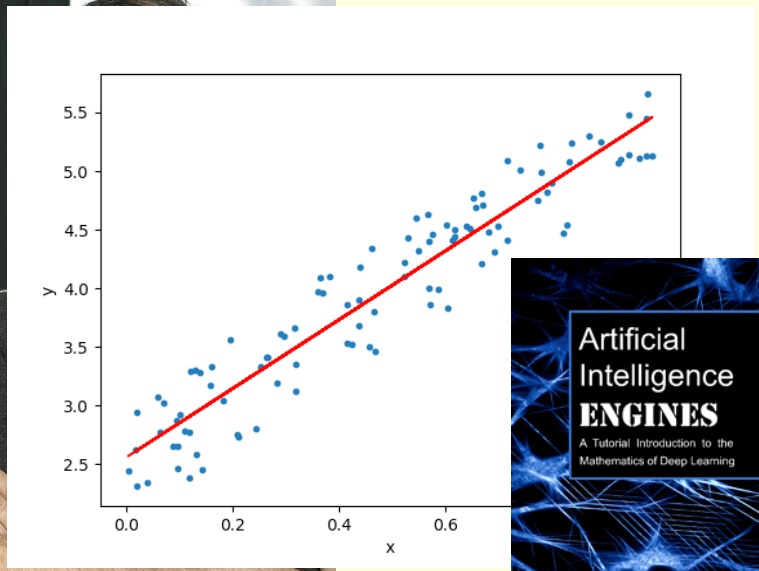


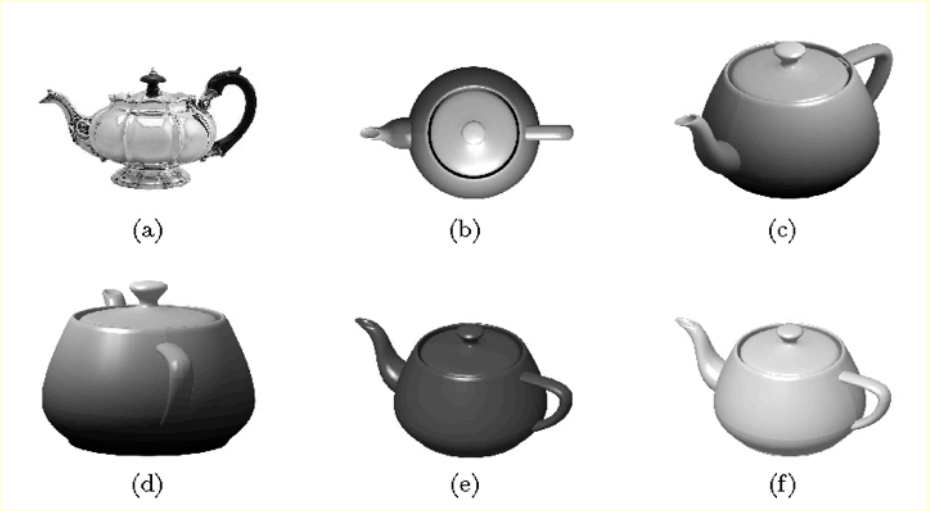
Figure 5.9 Examples of two-layer networks trained on 10 data points drawn from the sinusoidal data set. The graphs show the result of fitting networks having $M = 1$, 3 and 10 hidden units, respectively, by minimizing a sum-of-squares error function using a scaled conjugate-gradient algorithm.



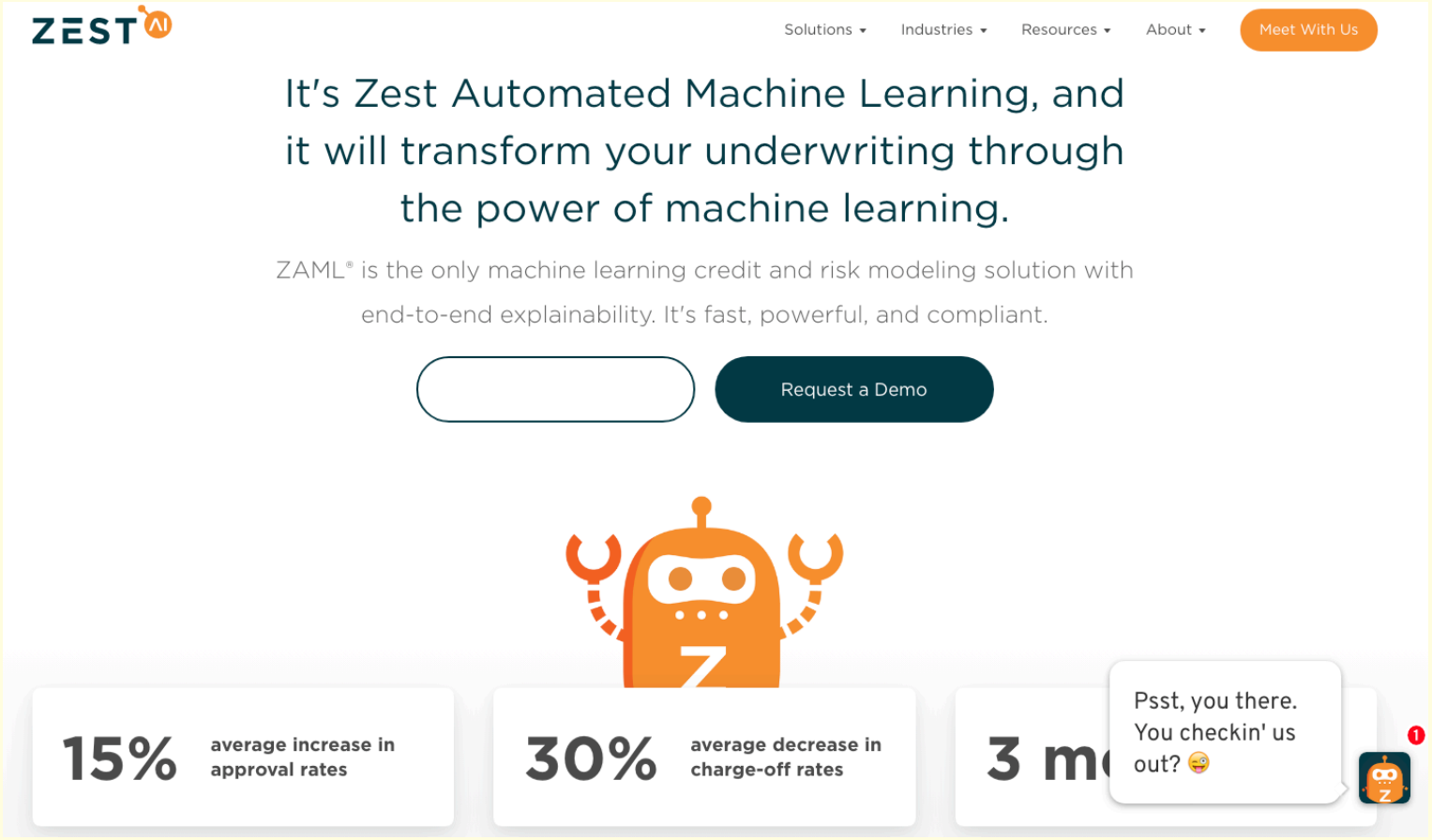


What can deep neural networks do? Why object recognition is hard

- Basically, objects can appear at any size/orientation/colour.
- Consider a square (black and white) image of 1,000 × 1,000 pixels.
- If each pixel can adopt 256 grey-levels then the number of possible images is $256^{1,000,000}$ (atoms in the universe = 10^{87}).
- Most of these $256^{1,000,000}$ possible images look like random noise, and only a tiny fraction depict anything approaching a natural scene — and only a fraction of those depict a teapot.
- If a network is to discriminate between teapots and non-teapots then it implicitly must assign a probability to each of the $256^{1,000,000}$ possible images.



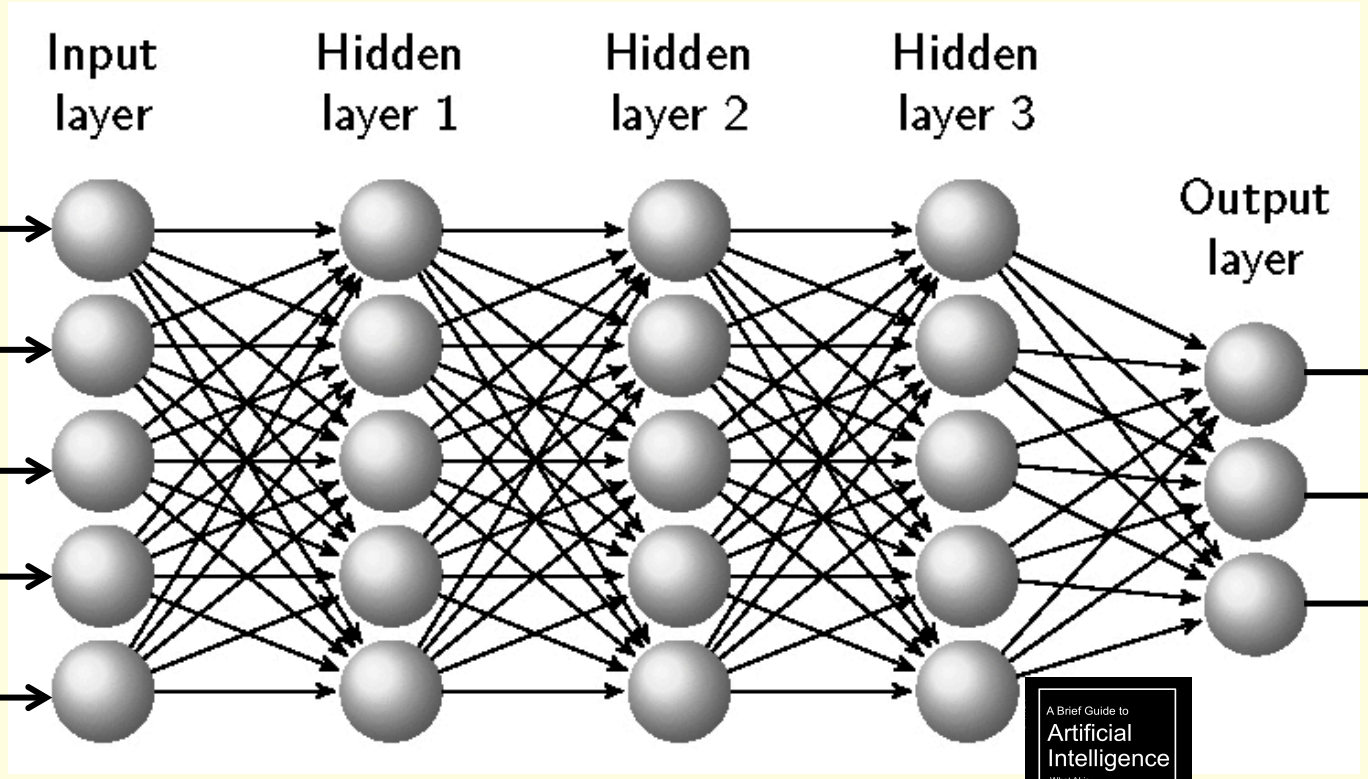
What can deep neural networks do?

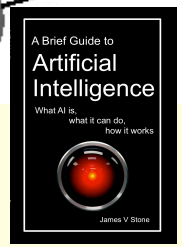


A neural network for car insurance

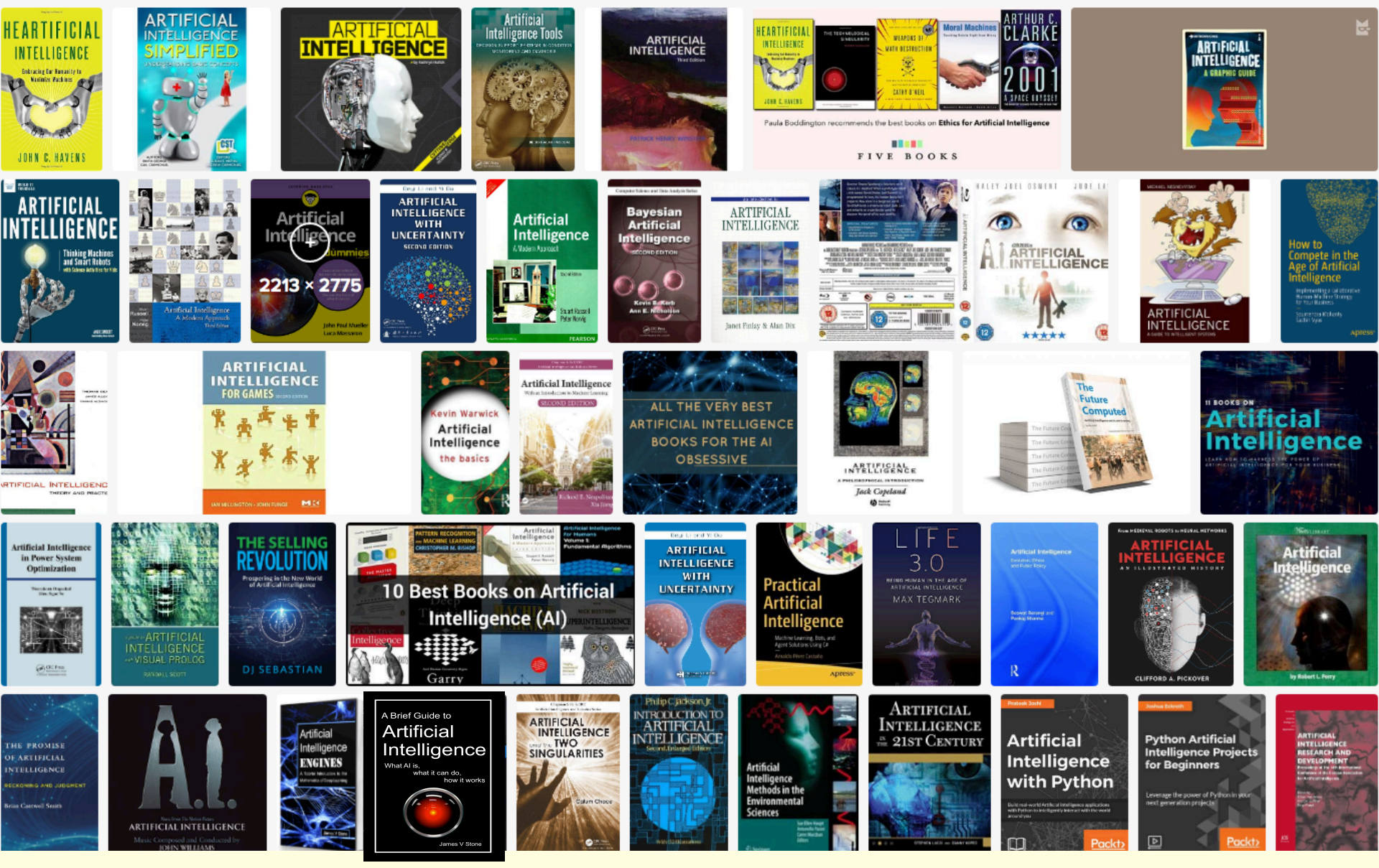
Input variables

Output variables





Artificial Intelligence Books



Go

World champion: Ke Jie said,

“Last year, I think the way AlphaGo played was pretty close to human beings, but today I think he plays like the God of Go”.

Is AI Biased?

- Yes, if it is given biased data.