Deep Learning Neural Networks

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

James V Stone, University of Sheffield

Structure

What is a deep learning neural network?

What can neural networks do?

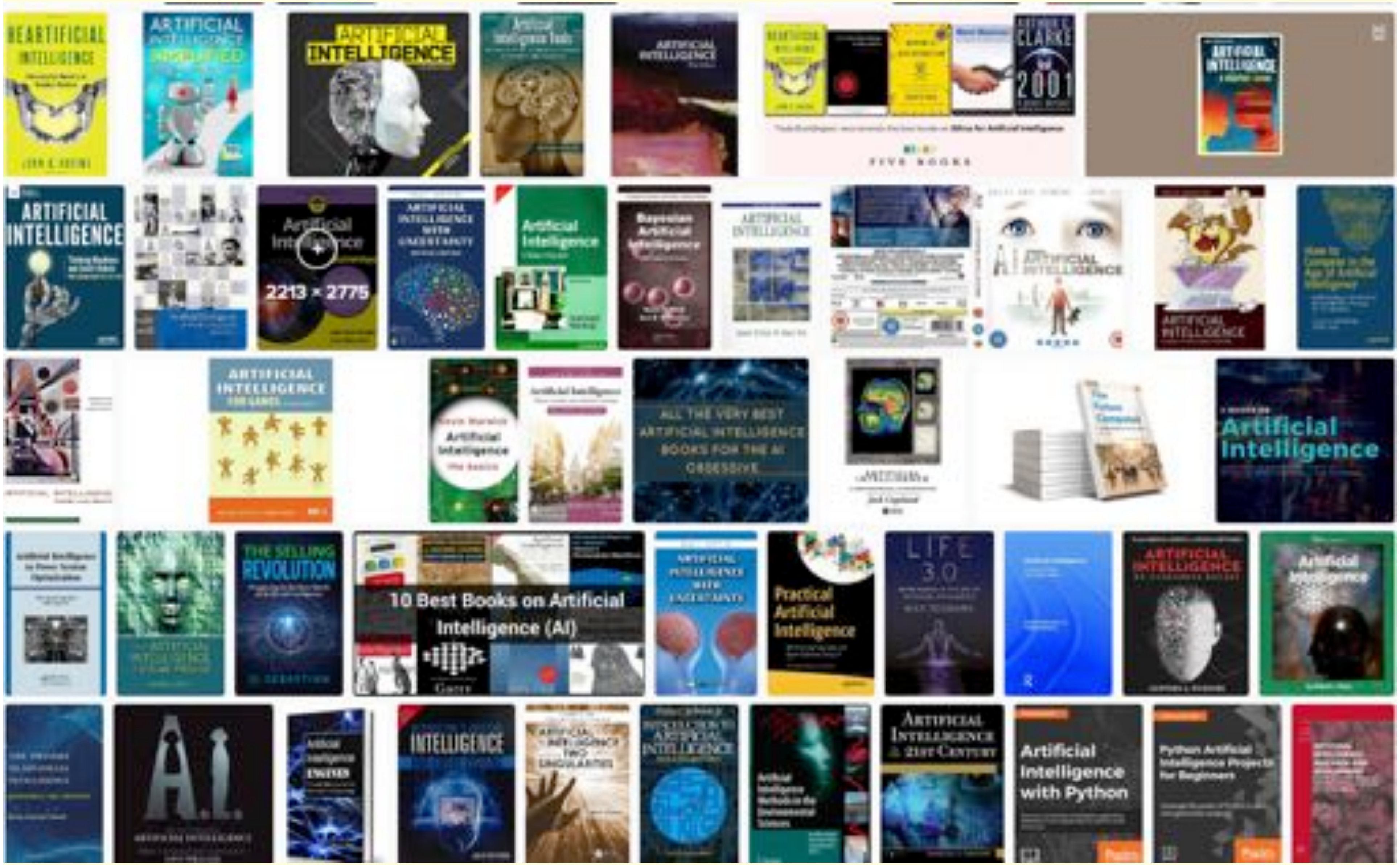
History of AI

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

What can neural networks NOT do?

Conclusion

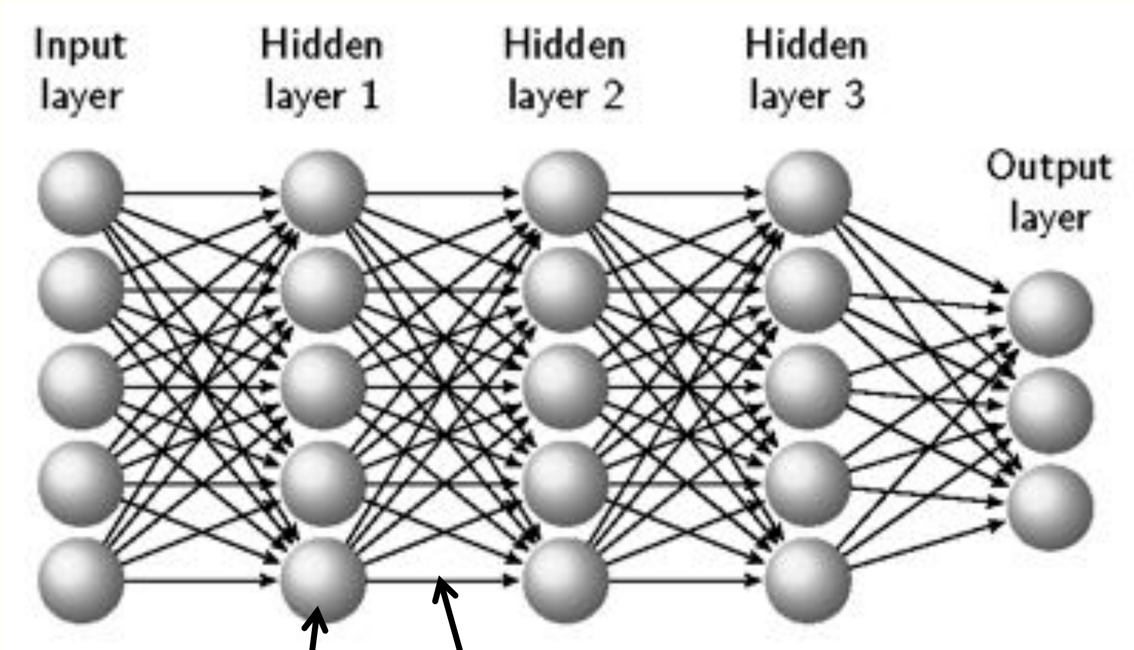
Artificial Intelligence Books



What is a deep learning neural network?

What is a deep learning neural network?

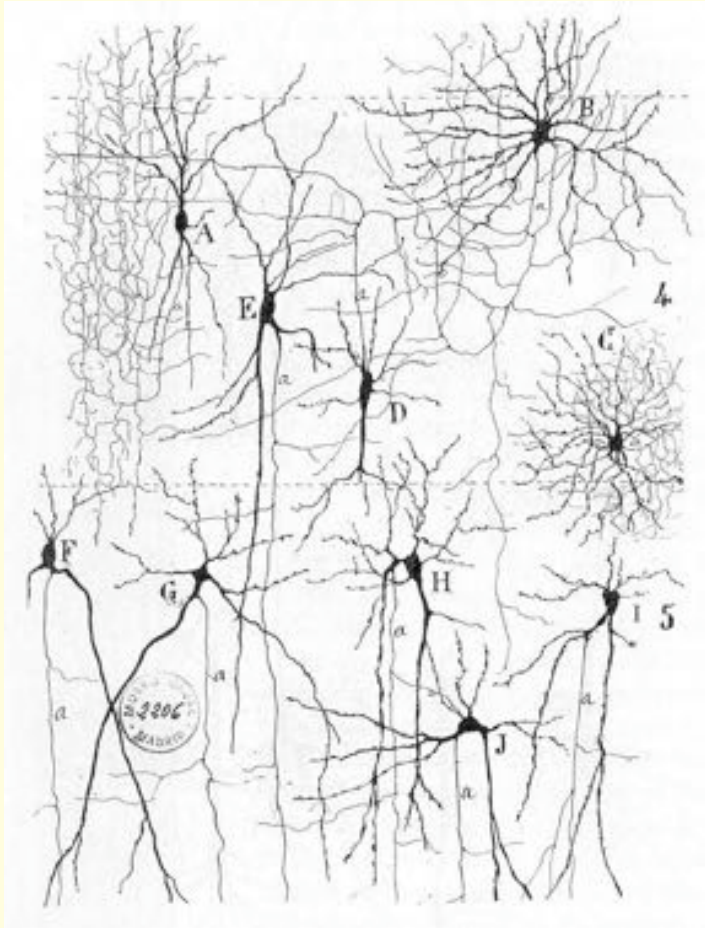
Deep learning network



unit

weight

Cajal’s drawing of neurons, 1900



Three similarities to human memory

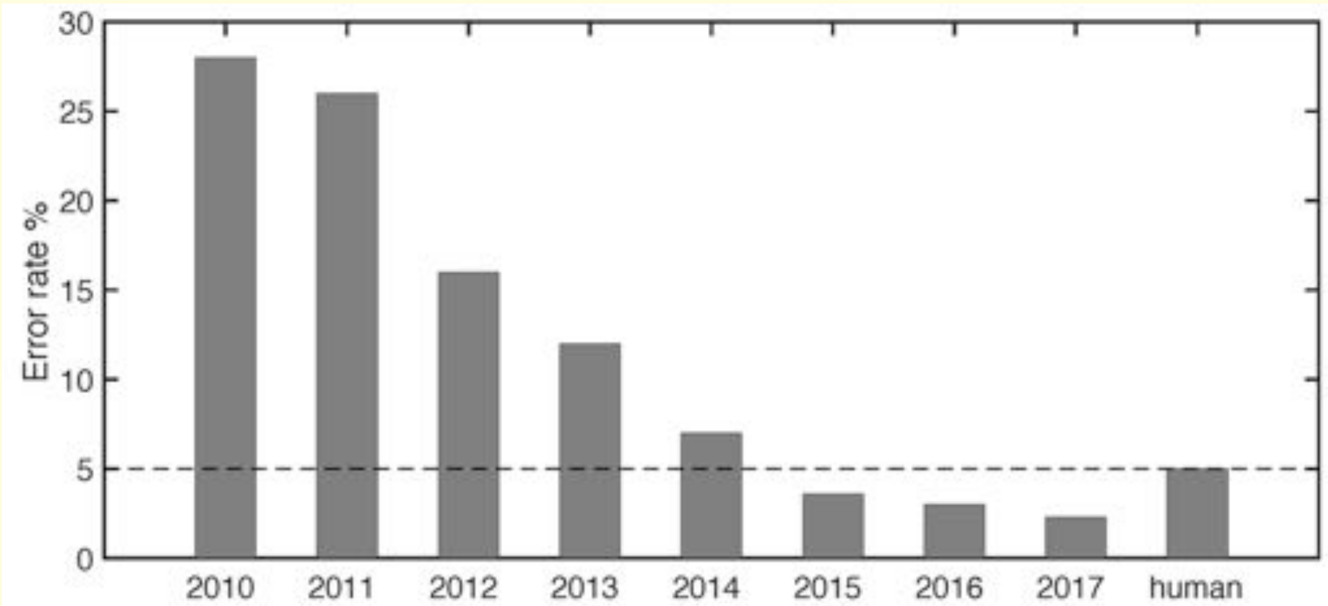
1) ***Content Addressable.*** Neural network memories are ***content addressable***, so recall is triggered by an image or a sound. In contrast, a computer memory can be accessed only if the specific location (address) of the required information is known.

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.

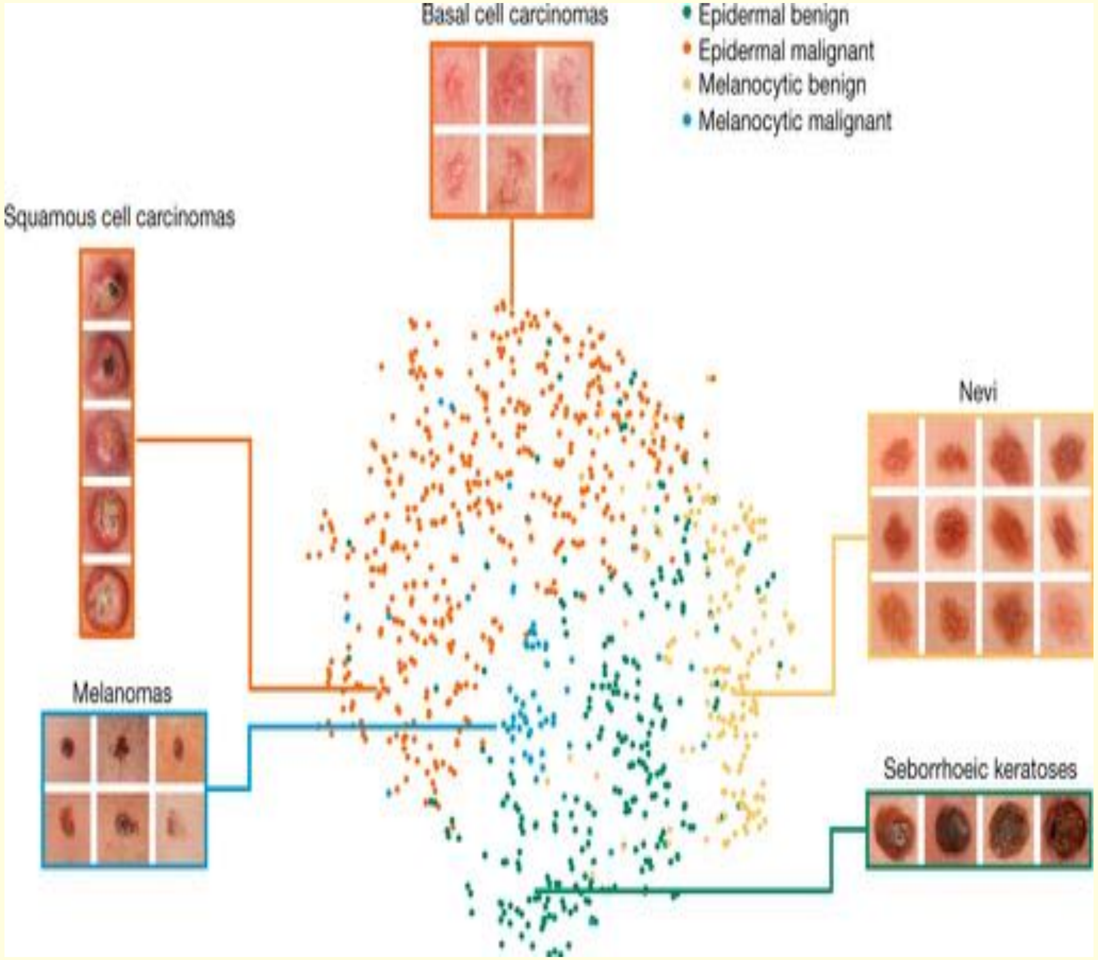
What can deep neural networks do? Classifying Images

- 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.



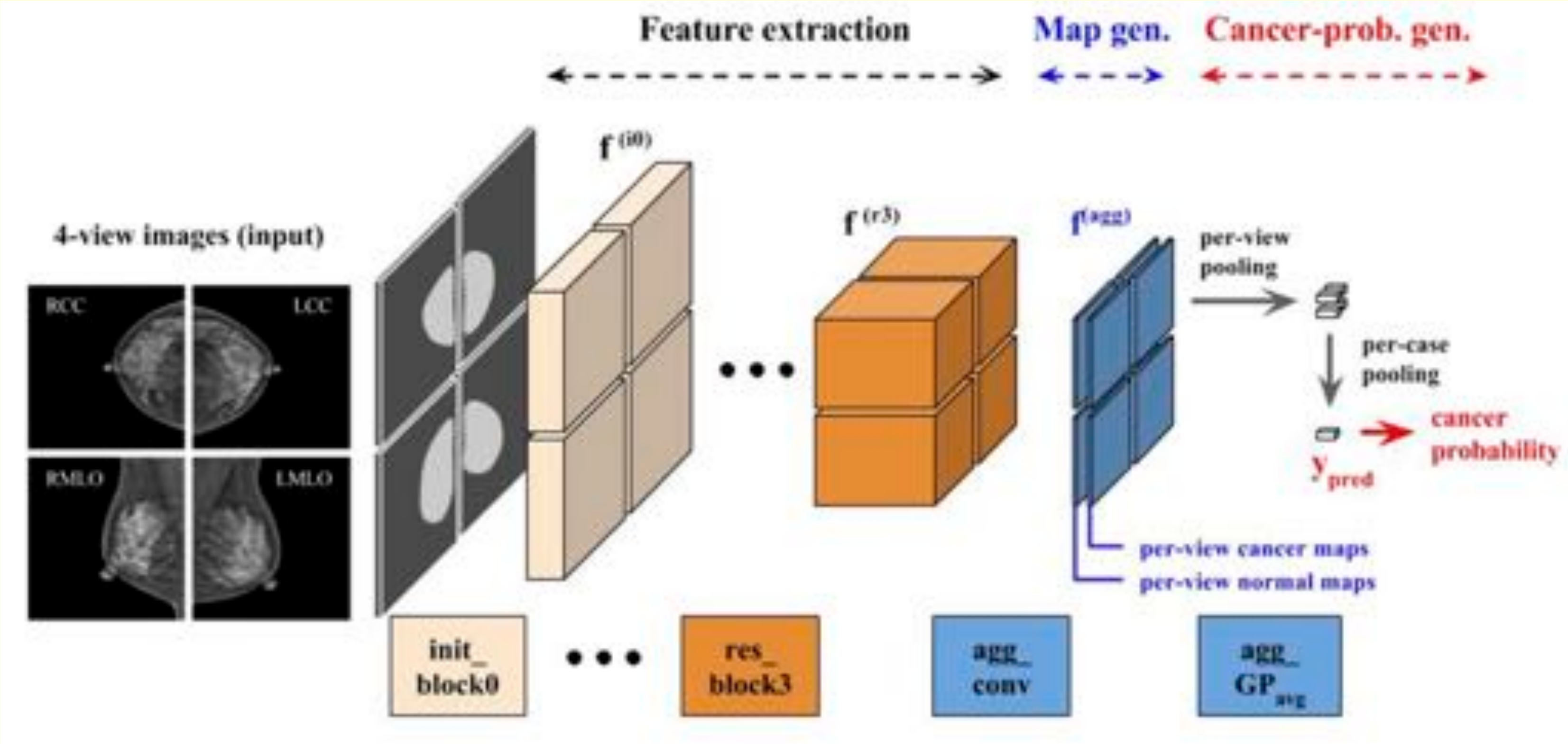
Reproduced with permission from Wu and Gu (2015).

What can deep neural networks do?
Medical diagnosis



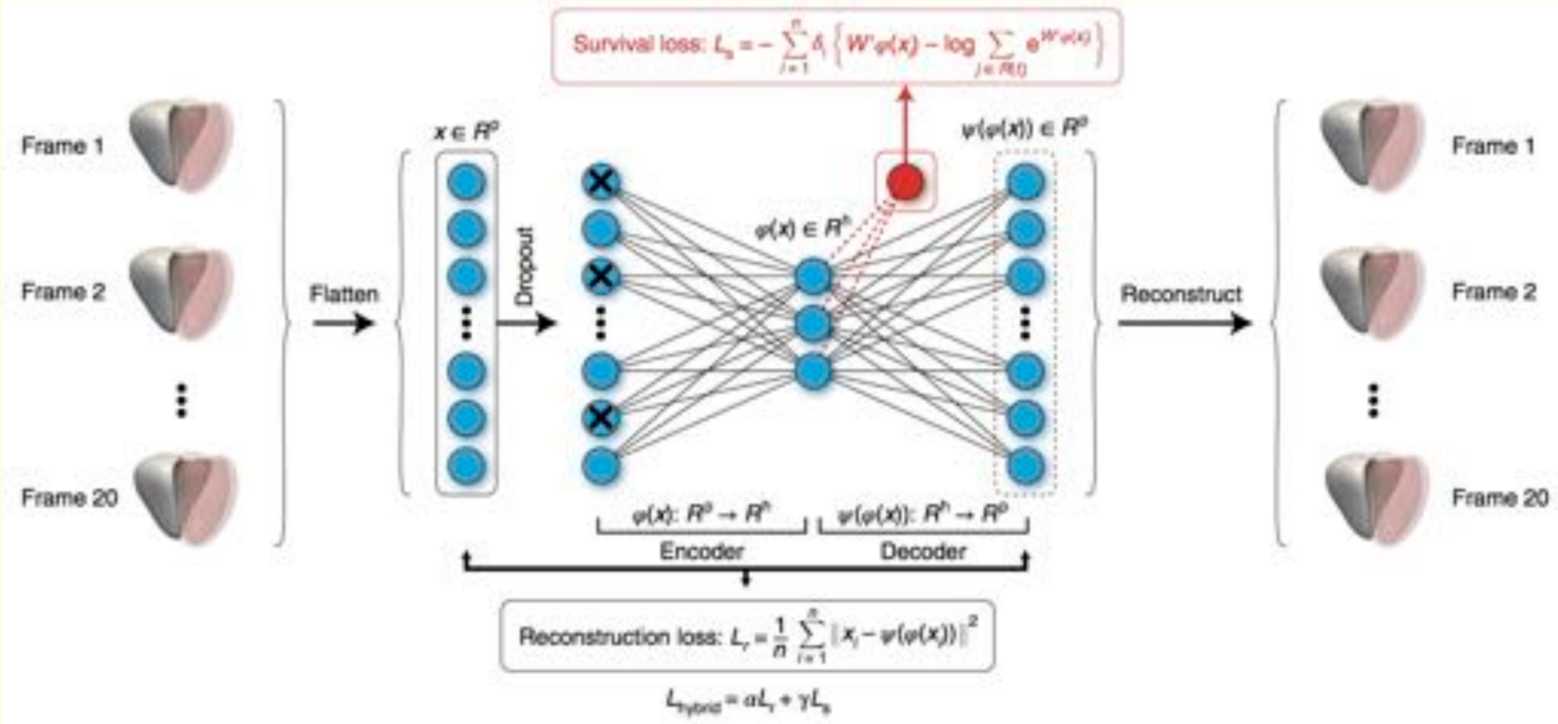
The Convolutional Neural Ntwork's representation of four important disease classes of melanoma (skin cancer). 2017

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.

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.

What can deep neural networks do?
Image Inpainting

Before | During | After

by NVIDIA

What can deep neural networks do?
Synthetic celebrity faces

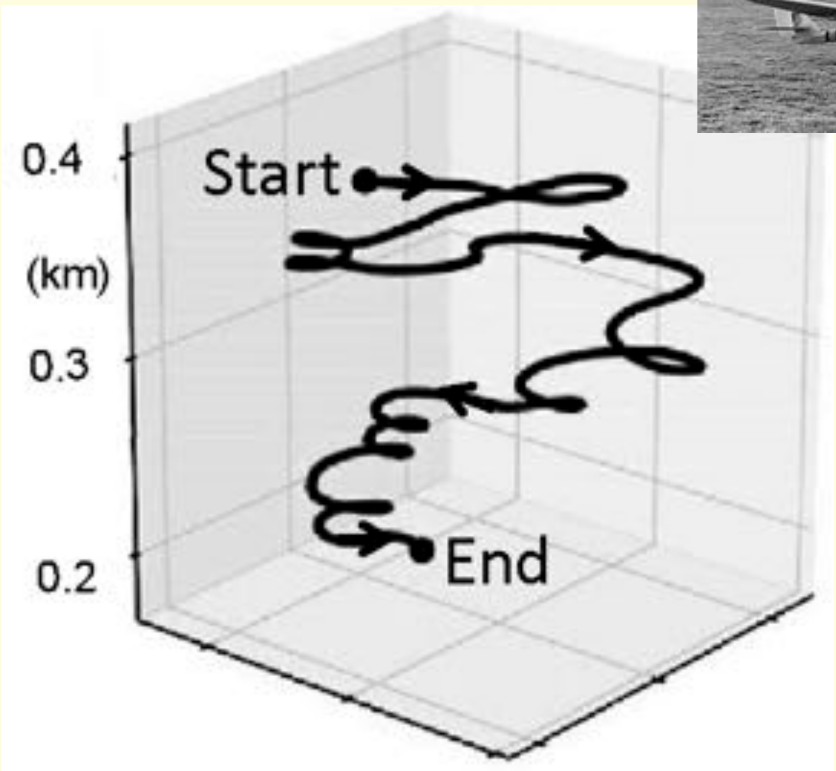
These people
do not exist

Karras, 2018

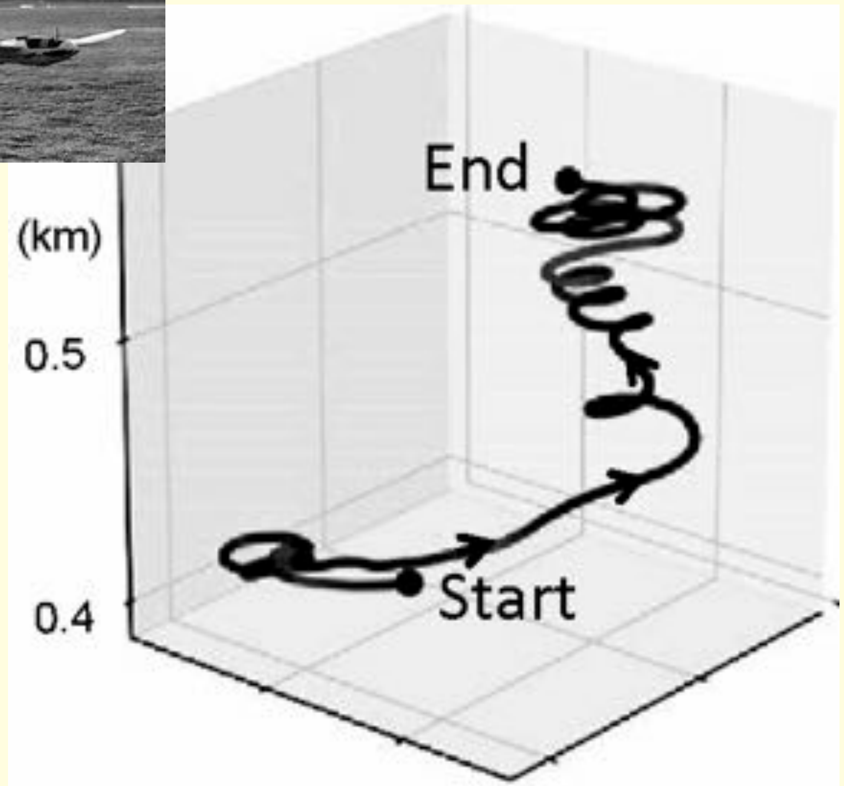
What can deep neural networks do? Cycling

View from above of cycle tracks. Randlov et al 1998

What can deep neural networks do?
Flying



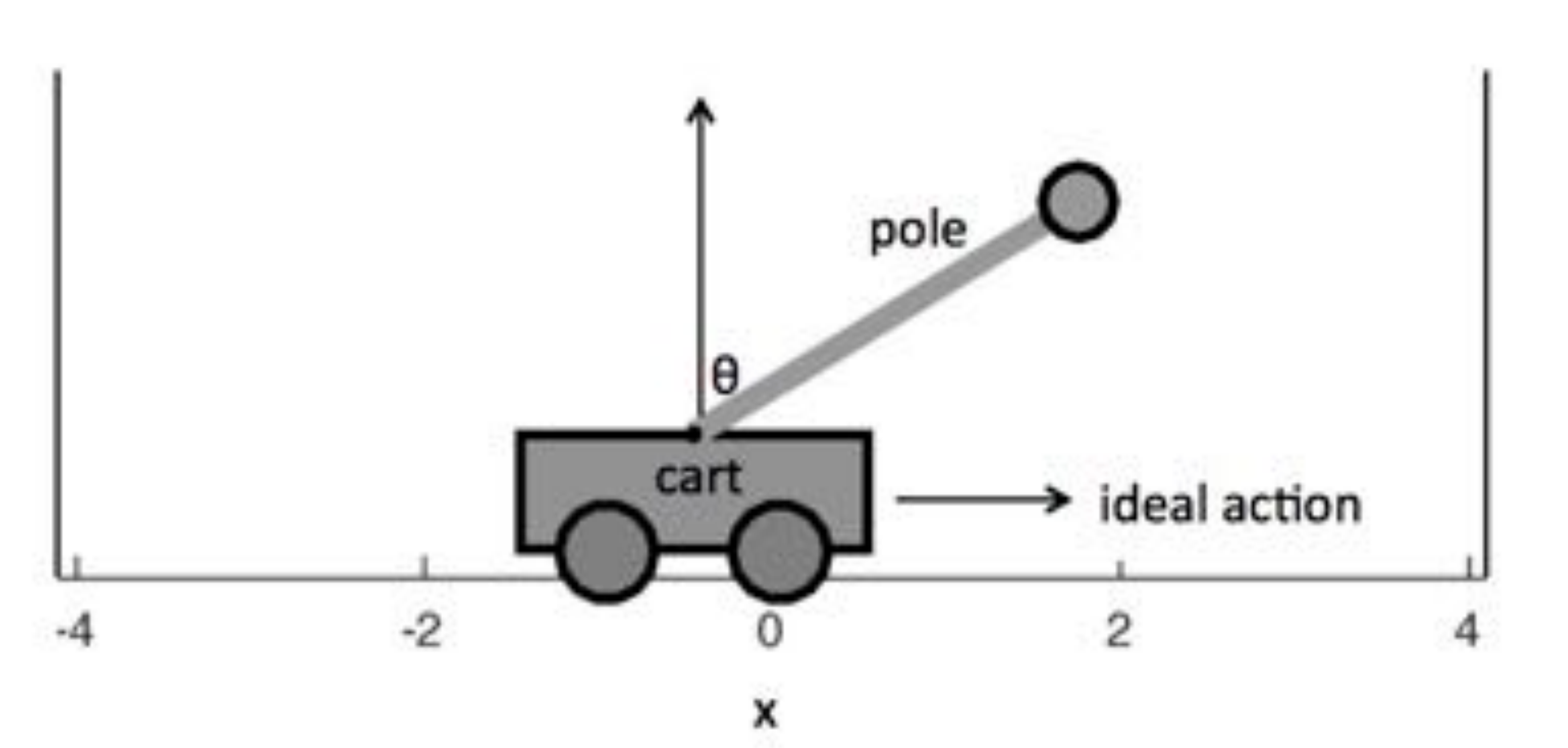
Before learning



After learning

Reddy et al 2016/18

What can deep neural networks do?
Balancing a pole



Sutton and Barto 1998-present

What can deep neural networks do?

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.

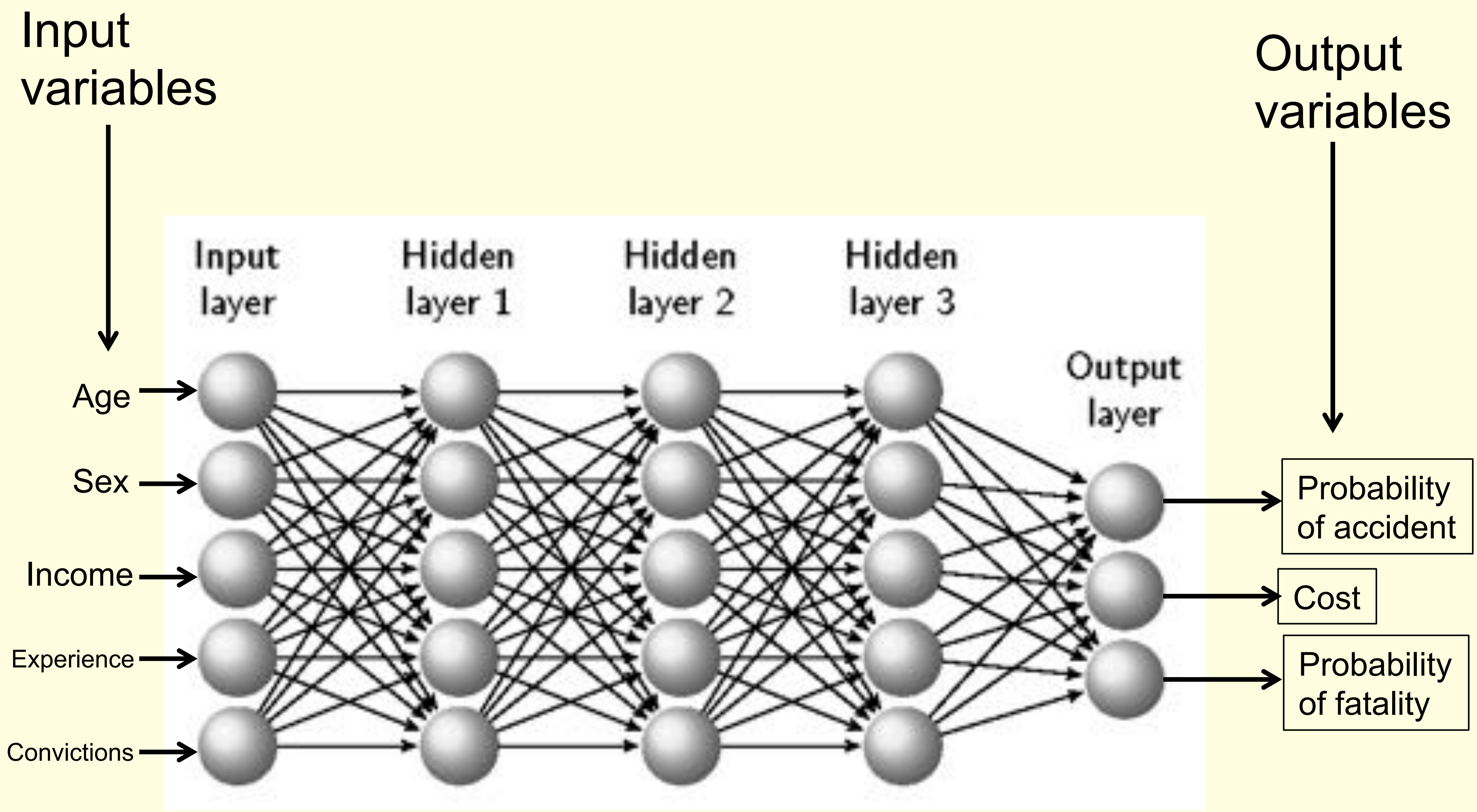
Science, August 2019.

What can deep neural networks do? Go and Chess

- 2016: AlphaGo defeated Go grandmaster Lee Sedol.

- 2017: AlphaGo Zero beat AlphaGo.
- 2018: Alpha for chess, shogi (Japanese chess), and Go, beating a world-champion program in each case.

A neural network for car insurance



History of AI

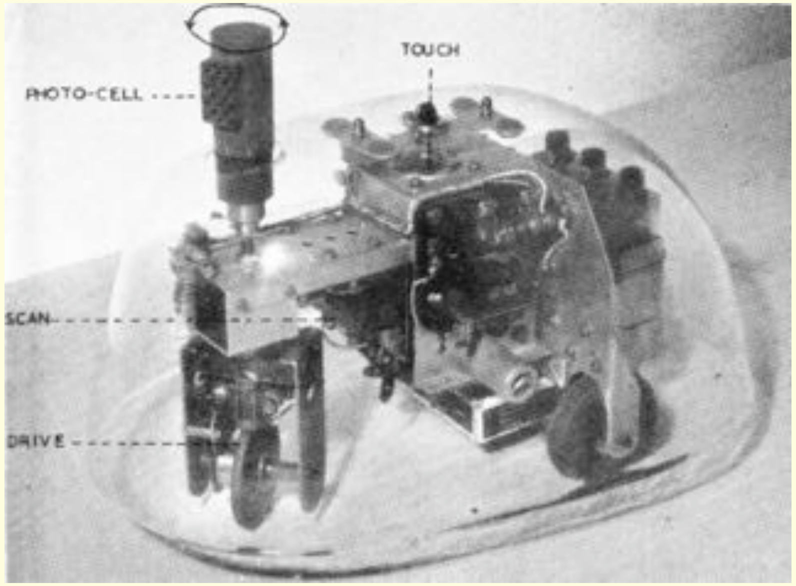
AI Before Artificial Neural Networks (1/2)

Pierre Jaquet-Droz, The Writer, 1770

Ada Lovelace and Charles Babbage's Analytical Engine, 1842

AI Before Artificial Neural Networks (2/2)

Gray Walter's Turtle 1948



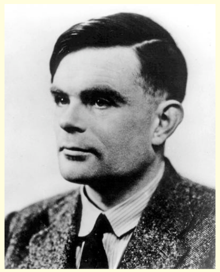
Claude Shannon's
Theseus Mouse, 1950

Key Developments: 1/4

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

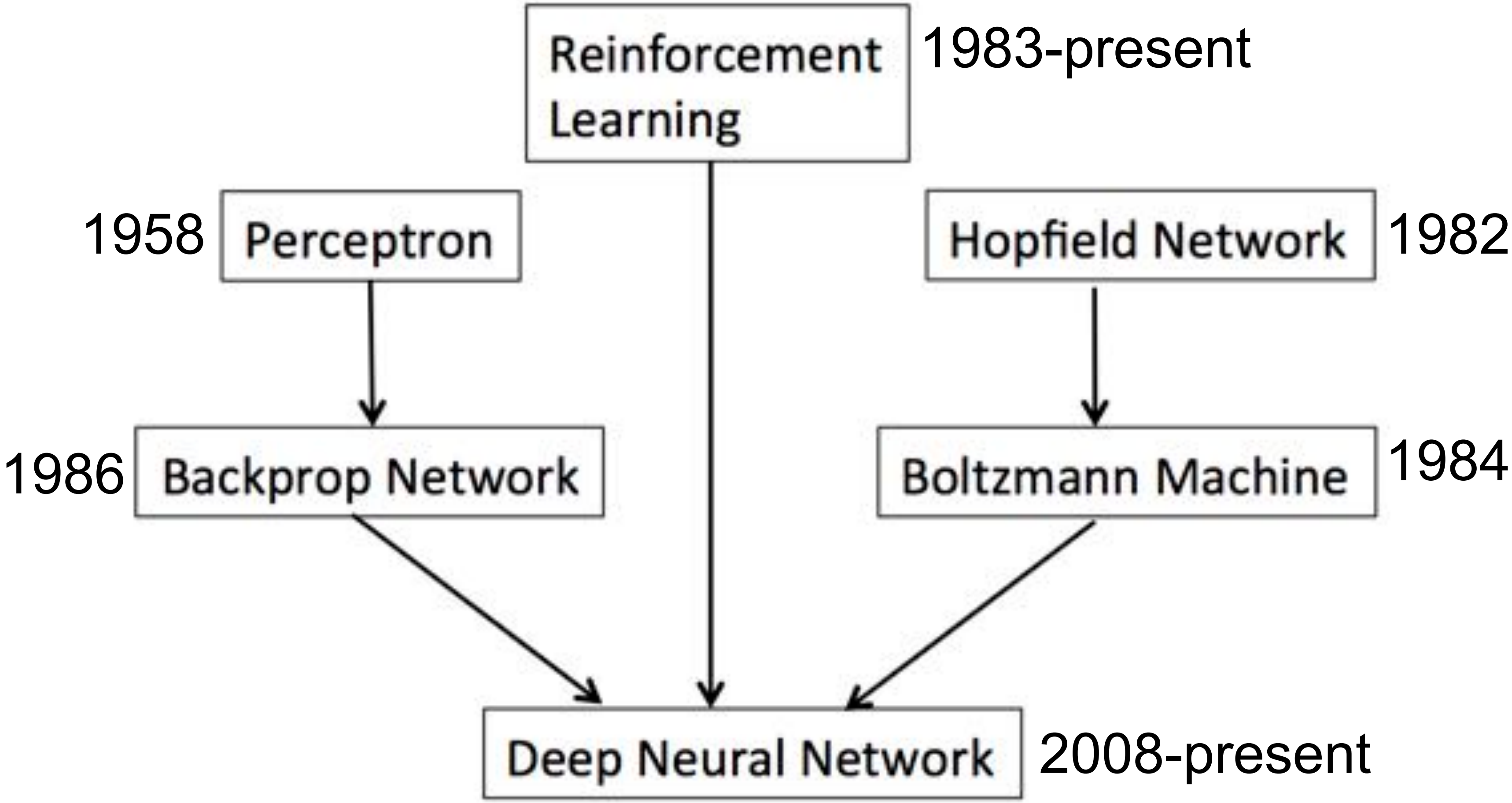
1949: Donald Hebb.
“The Organization of Behavior”

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



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

Neural Networks History: 1983-present



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

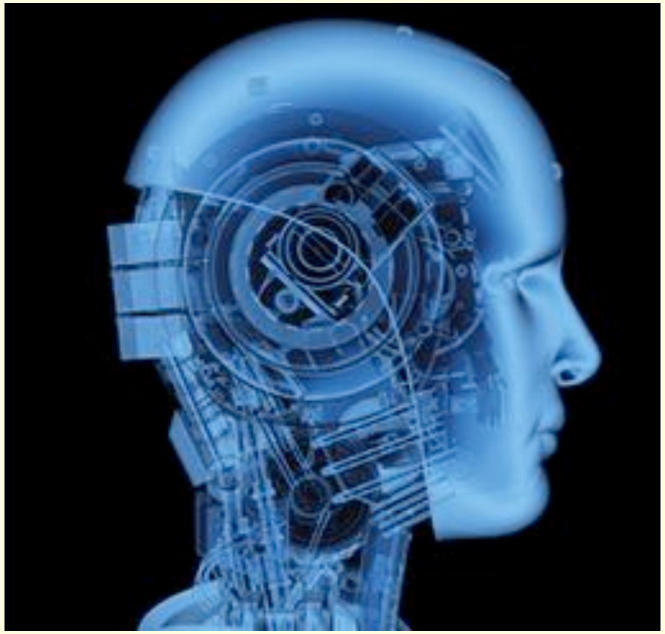
"Mastering the game of Go with Deep Neural Networks & Tree Search", Silver, Huang, et al. Nature 2016

defeated Go grandmaster Lee Sedol. (see below)

What can deep neural networks NOT do?

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

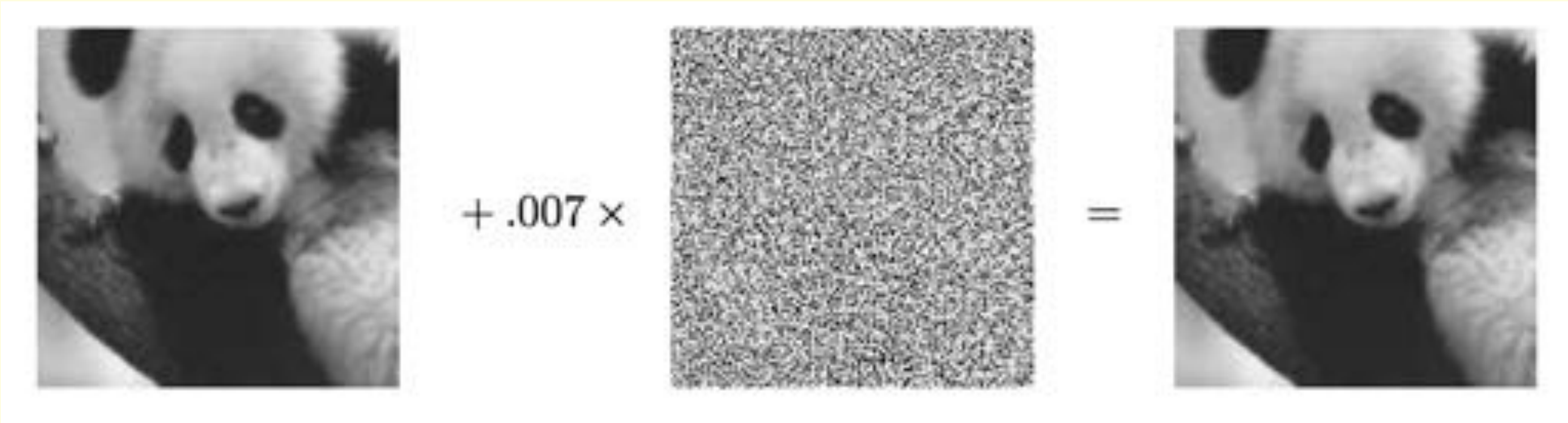
What can deep neural networks NOT do?
Artificial Intelligence (yet)



AI in the press

AI in the computer

What can deep neural networks NOT do?
Robust object recognition



Classified as **panda**

Adversarial noise

Classified as **gibbon**

Goodfellow et al 2014

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

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 that 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

THE END

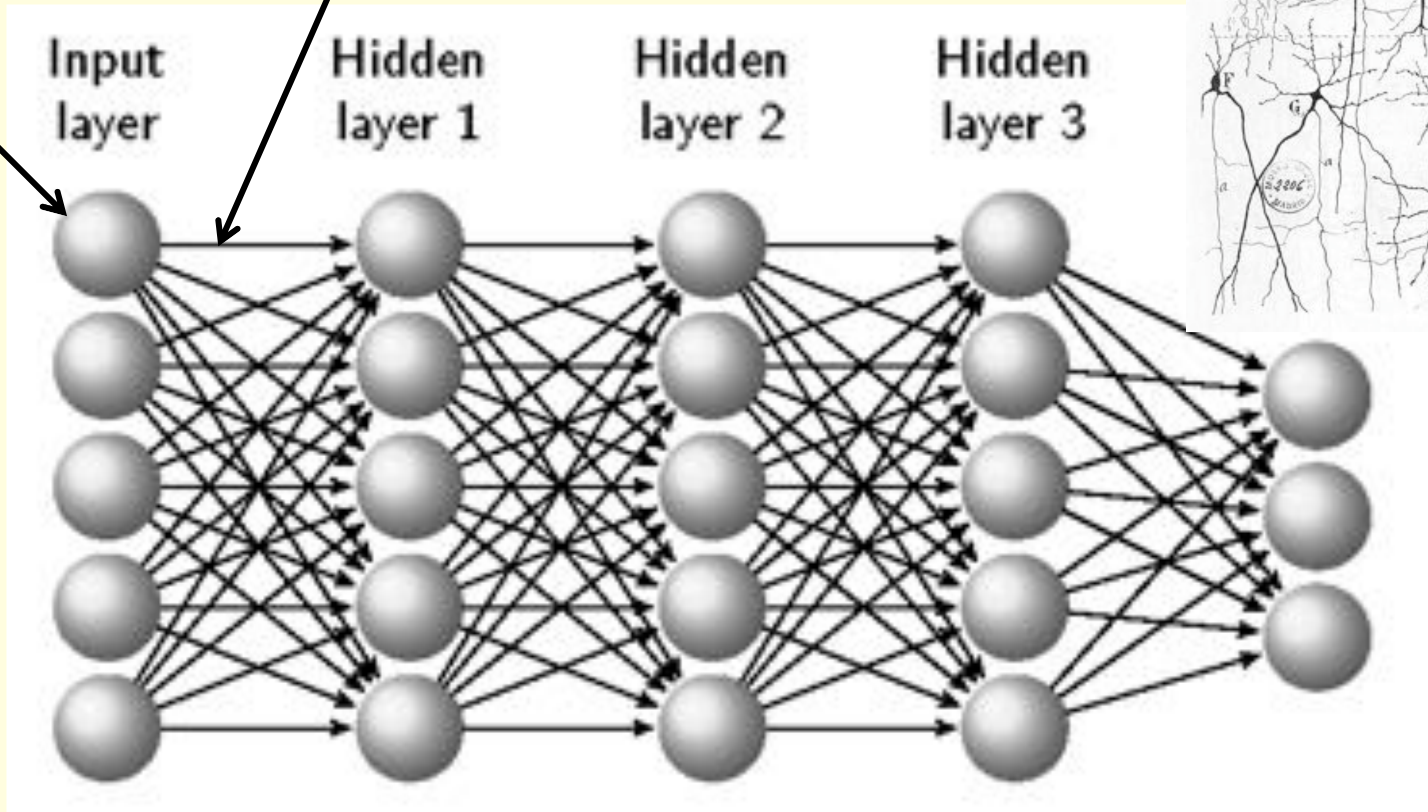
The Turing Day

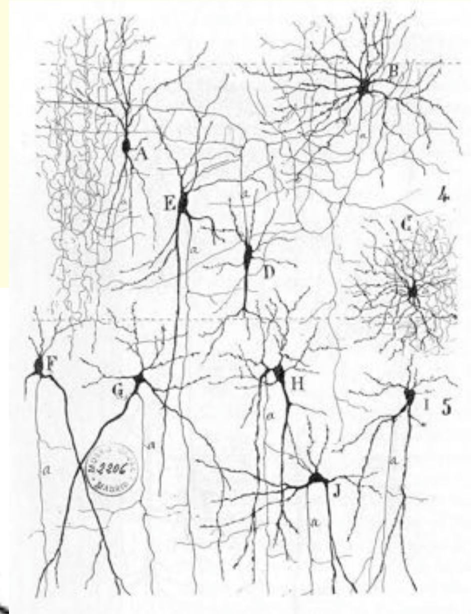
- The workshop will be mostly lectures followed by a lab session.
- 10:00-11:00 Introduction: Deep Learning and AI: What it is, what it can, and cannot do. JVS
- 11:00-12:00 Overview: From linear networks to convolutional networks. SJE
- 12:00-13:00 Lunch
- 13:00-14:00 Deep Learning using Gradient Descent: 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?

weight

unit





Spare pictures

- Object recognition
- Chess etc
- Flying
- Medical diagnosis

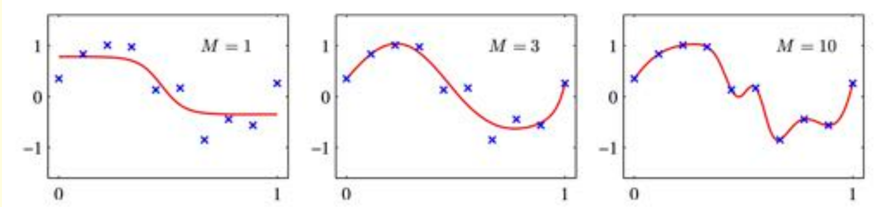
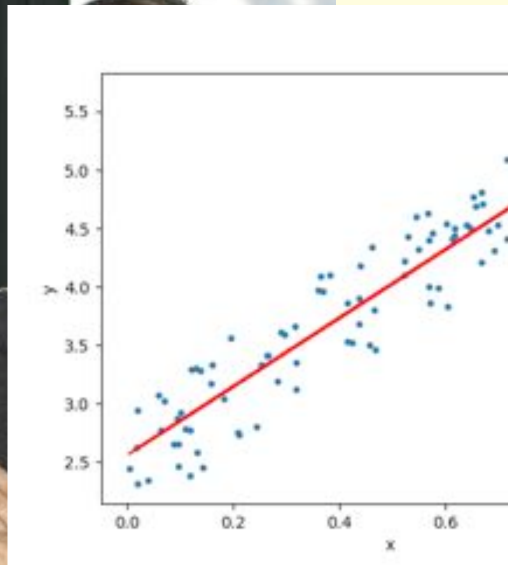
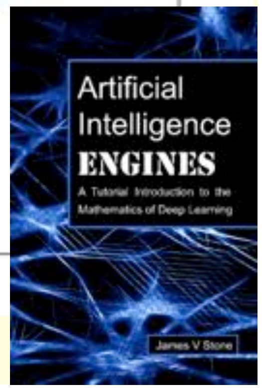


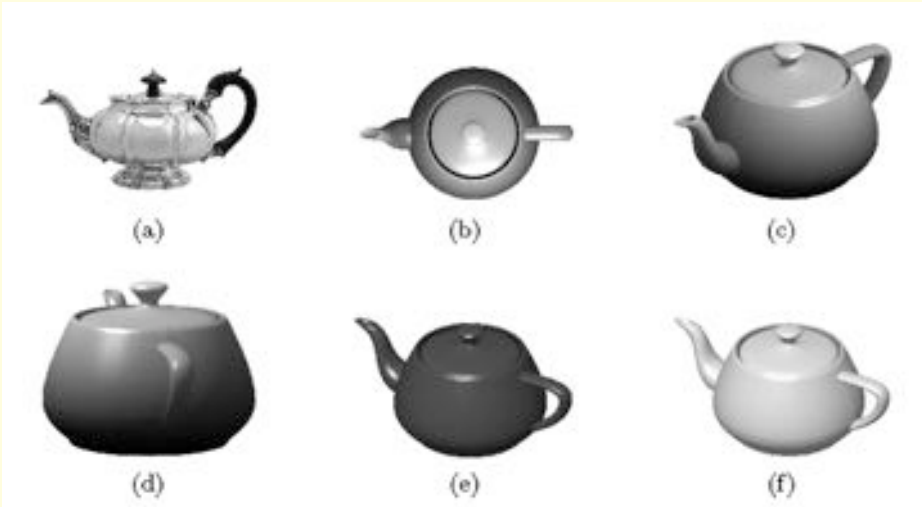
Figure 5.9 Examples of two-layer networks trained on 10 data points drawn from the sinusoidal data set. The graphs show the result of fitting networks having $M = 1$, 3 and 10 hidden units, respectively, by minimizing a sum-of-squares error function using a scaled conjugate-gradient algorithm.





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?