Artificial Intelligence

ACTL3143 & ACTL5111 Deep Learning for Actuaries

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Lecture Outline

- **Artificial Intelligence**
- Machine Learning
- Machine Learning Paradigms
- Neural Networks

Different goals of AI

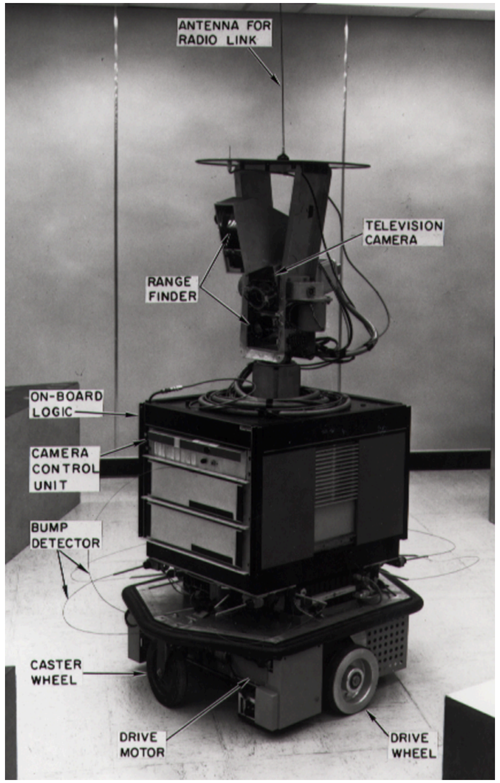
Artificial intelligence describes an agent which is capable of:

Thinking humanly	Thinking rationally
Acting humanly	Acting rationally

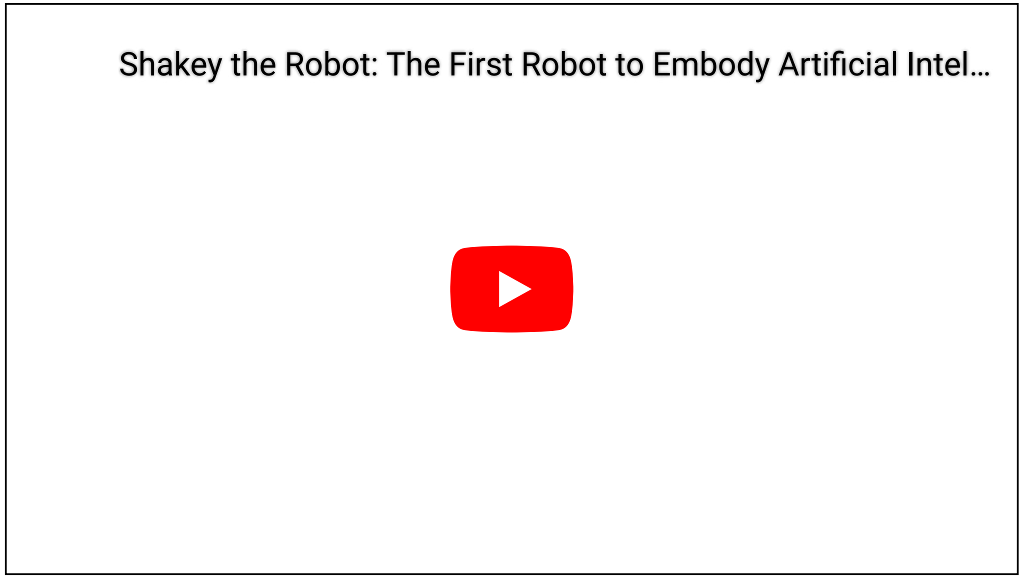
AI eventually become dominated by one approach, called *machine learning*, which itself is now dominated by *deep learning* (neural networks).

There are AI algorithms for simple tasks that don't use machine learning though.

Shakey the Robot (~1966 – 1972)

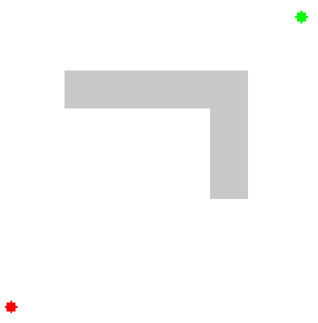


Shakey the Robot



Route-finding I

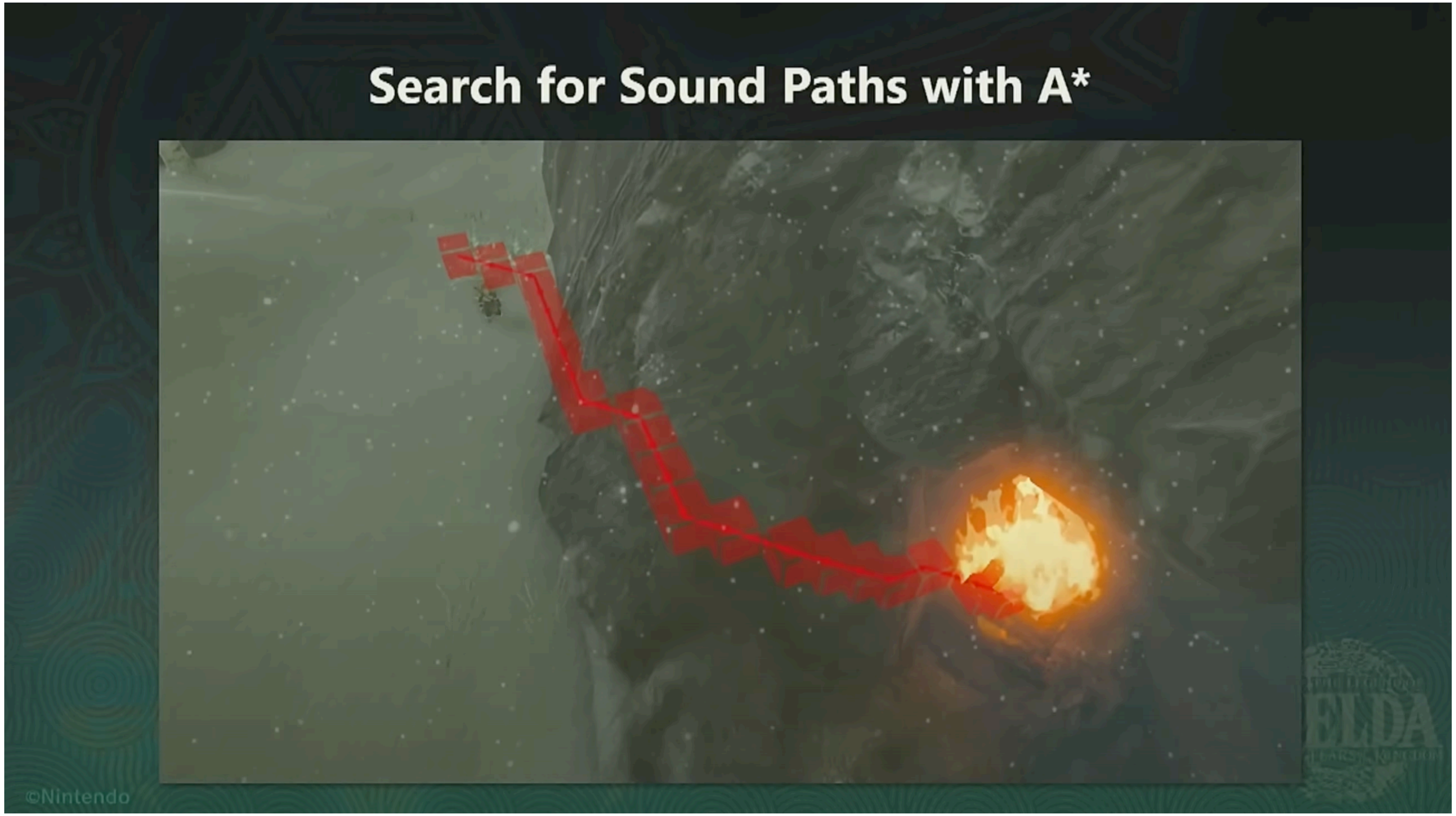
> At its core, a pathfinding method searches a graph by starting at one vertex and exploring adjacent nodes until the destination node is reached, generally with the intent of finding the cheapest route. Although graph searching methods such as a breadth-first search would find a route if given enough time, other methods, which "explore" the graph, would tend to reach the destination sooner. An analogy would be a person walking across a room; rather than examining every possible route in advance, the person would generally walk in the direction of the destination and only deviate from the path to avoid an obstruction, and make deviations as minor as possible. (Source: Wikipedia)



A* algorithm (1968).

Source: Wikipedia page for the A* search algorithm.

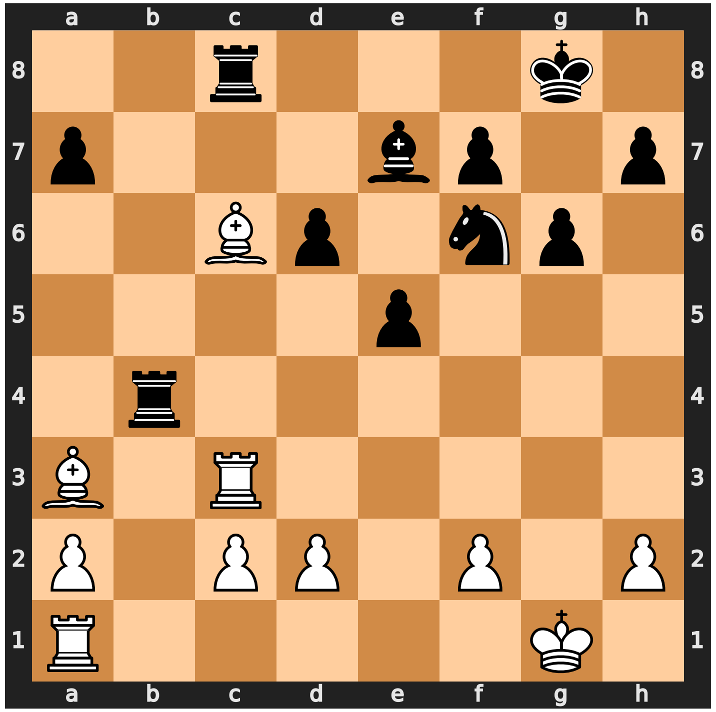
Route-finding II



Tunes of the Kingdom: Evolving Physics and Sounds for ‘The Legend of Zelda: Tears of the Kingdom’, GDC 2024

Evaluating a chess game I

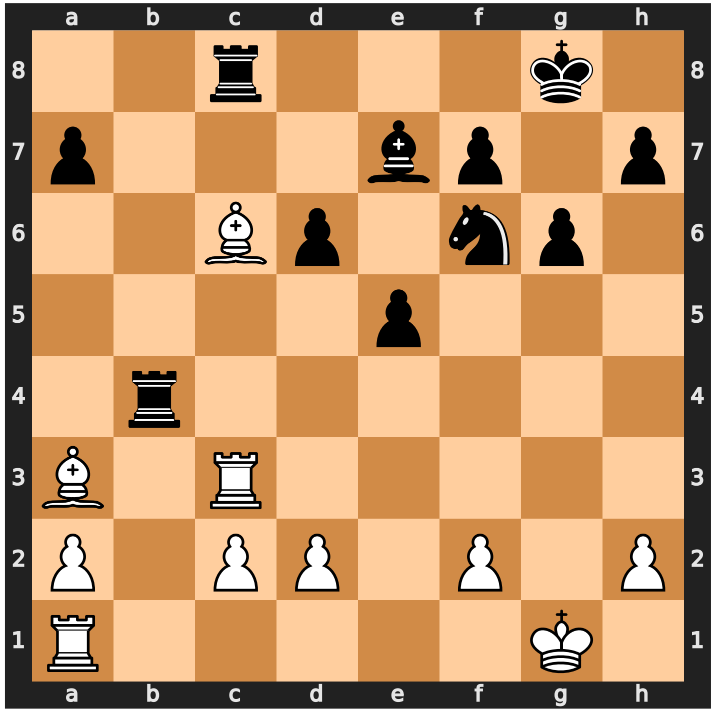
Who’s winning this game?



♙	$5 \times 1 = 5$
♘	$0 \times 3 = 0$
♗	$2 \times 3 = 6$
♖	$2 \times 5 = 10$
♕	$0 \times 9 = 0$
♔	$1 \times 0 = 0$
White	21

Evaluating a chess game II

Just add up the pieces for each player.



♟	$6 \times 1 = 6$
♞	$1 \times 3 = 3$
♝	$1 \times 3 = 3$
♜	$2 \times 5 = 10$
♛	$0 \times 9 = 0$
♚	$1 \times 0 = 0$
Black	22

Overall: $21 - 22 = -1$.

The minimax algorithm

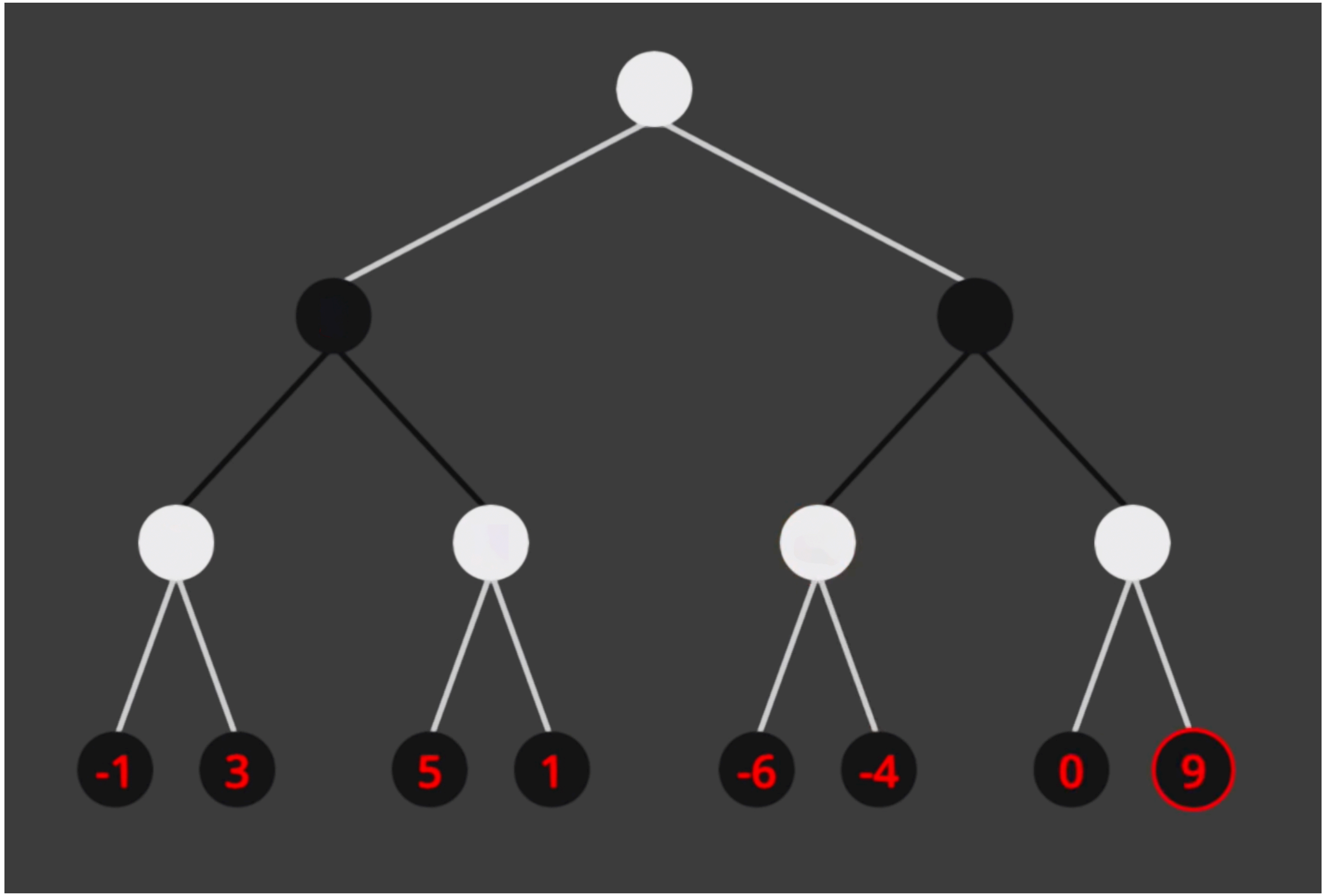


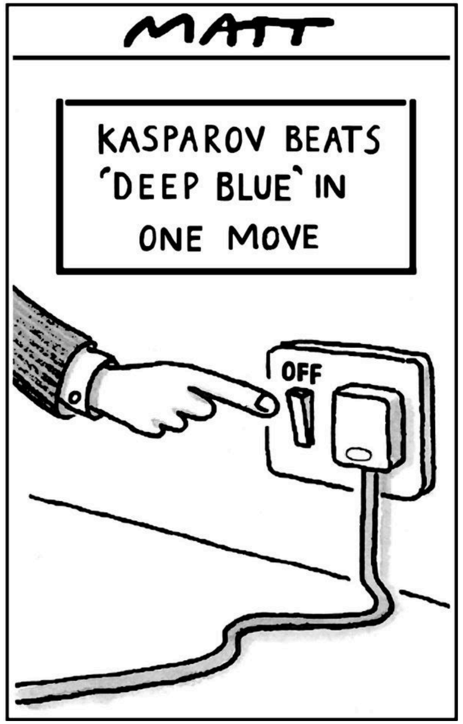
Illustration of minimax on a two-player game.

Source: Sebastian Lague (2018), Algorithms Explained – minimax and alpha-beta pruning.

Chess

Deep Blue (1997)

Gary Kasparov playing Deep Blue.



Cartoon of the match.

Sources: Mark Robert Anderson (2017), Twenty years on from Deep Blue vs Kasparov, The Conversation article, and Computer History Museum.

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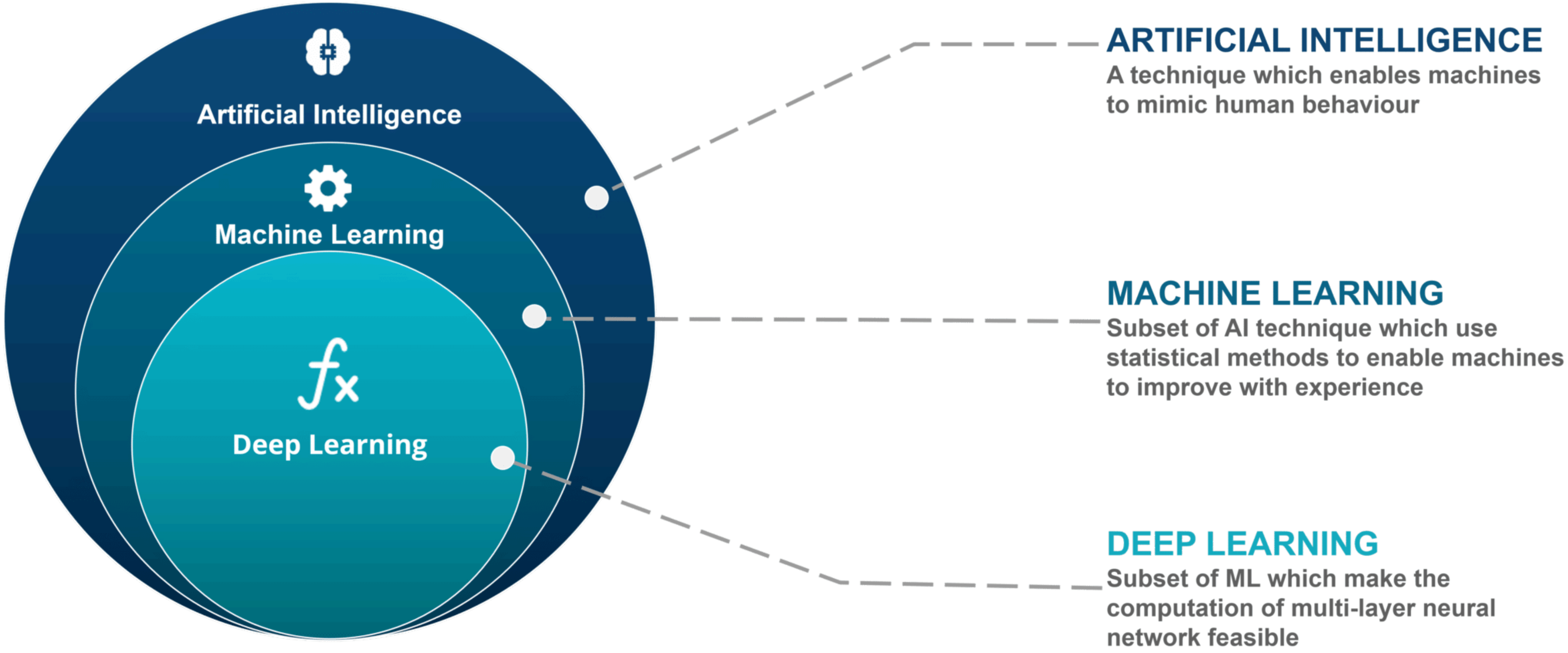
Main idea

Tried *making a computer smart*, too hard!

Make a computer that can **learn** to be smart.

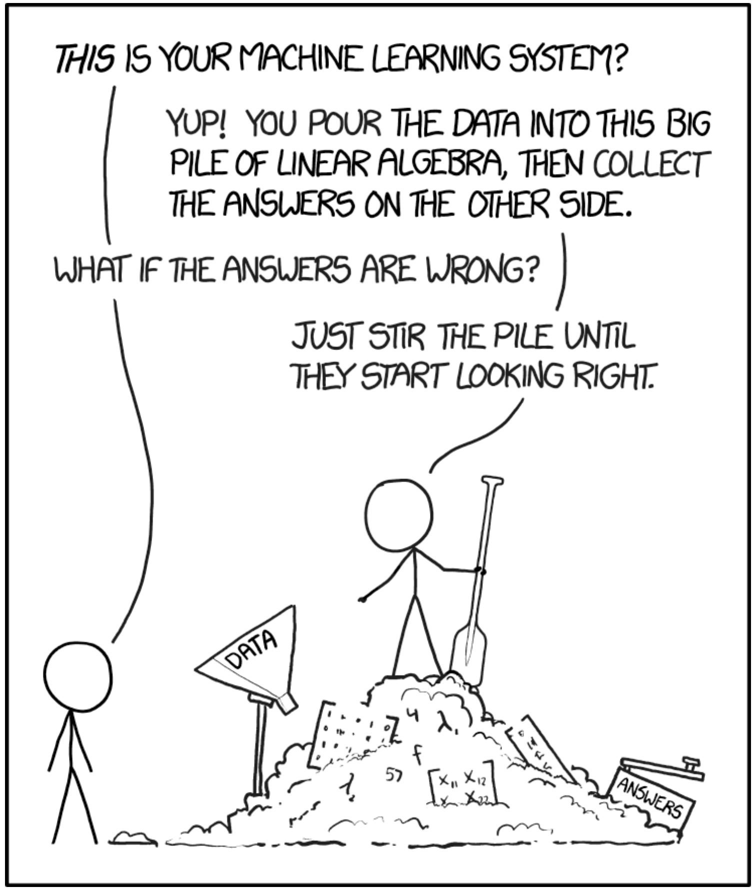


The Venn diagram of Artificial Intelligence, Machine Learning, and Deep Learning.

Source: Edureka (2020), AI Vs Machine Learning Vs Deep Learning Edureka.

Definition

> "[Machine Learning is the] field of study that gives computers the ability to learn without being explicitly programmed" Arthur Samuel (1959)



Source: Randall Munroe (2017), xkcd #1838: Machine Learning.

Image Classification I

What is this?

Options:

1. punching bag
2. goblet
3. red wine
4. hourglass
5. balloon

Note

Hover over the options to see AI's prediction (i.e. the probability of the photo being in that category).

Source: Wikipedia

Image Classification II

What is this?

Options:

1. sea urchin
2. porcupine
3. echidna
4. platypus
5. quill

Source: Wikipedia

Image Classification III

What is this?

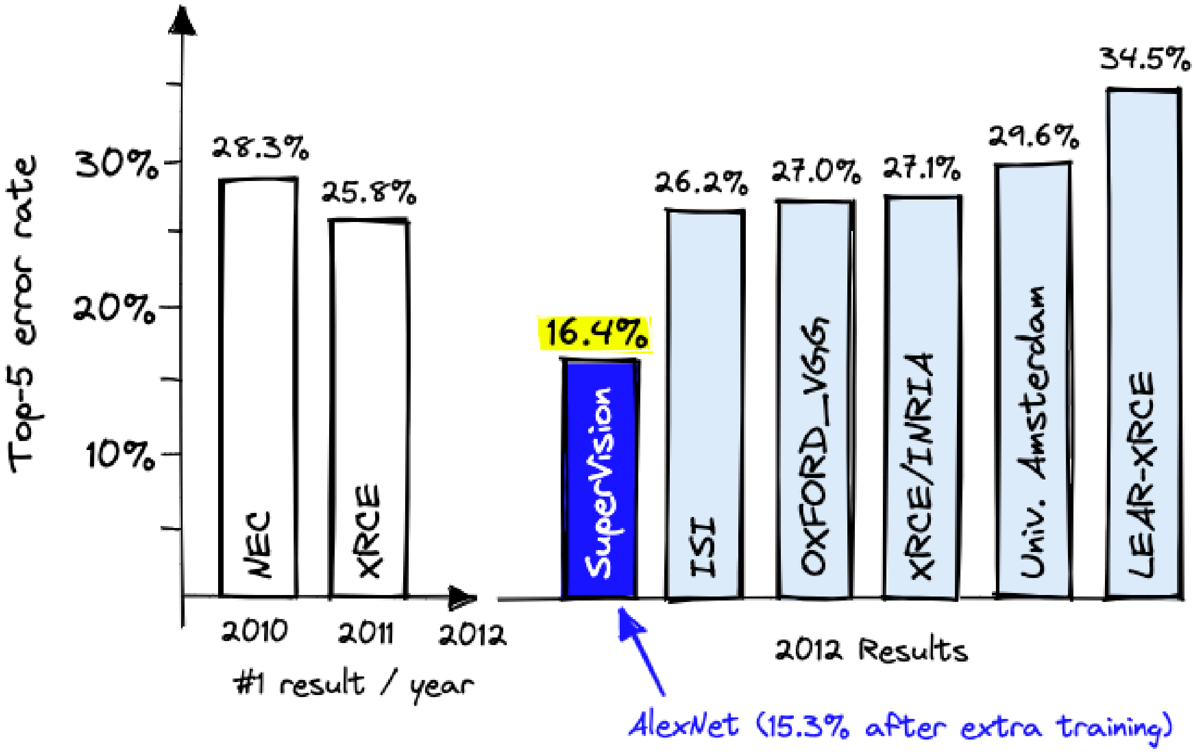
Options:

1. dingo
2. malinois
3. German shepherd
4. muzzle
5. kelpie

Source: Wikipedia

ImageNet Challenge

ImageNet and the *ImageNet Large Scale Visual Recognition Challenge (ILSVRC)*; originally 1,000 synsets.



AlexNet — a neural network developed by Alex Krizhevsky, Ilya Sutskever, and Geoffrey Hinton — won the ILSVRC 2012 challenge convincingly.

Source: James Briggs & Laura Carnevali, *AlexNet and ImageNet: The Birth of Deep Learning*, Embedding Methods for Image Search, Pinecone Blog

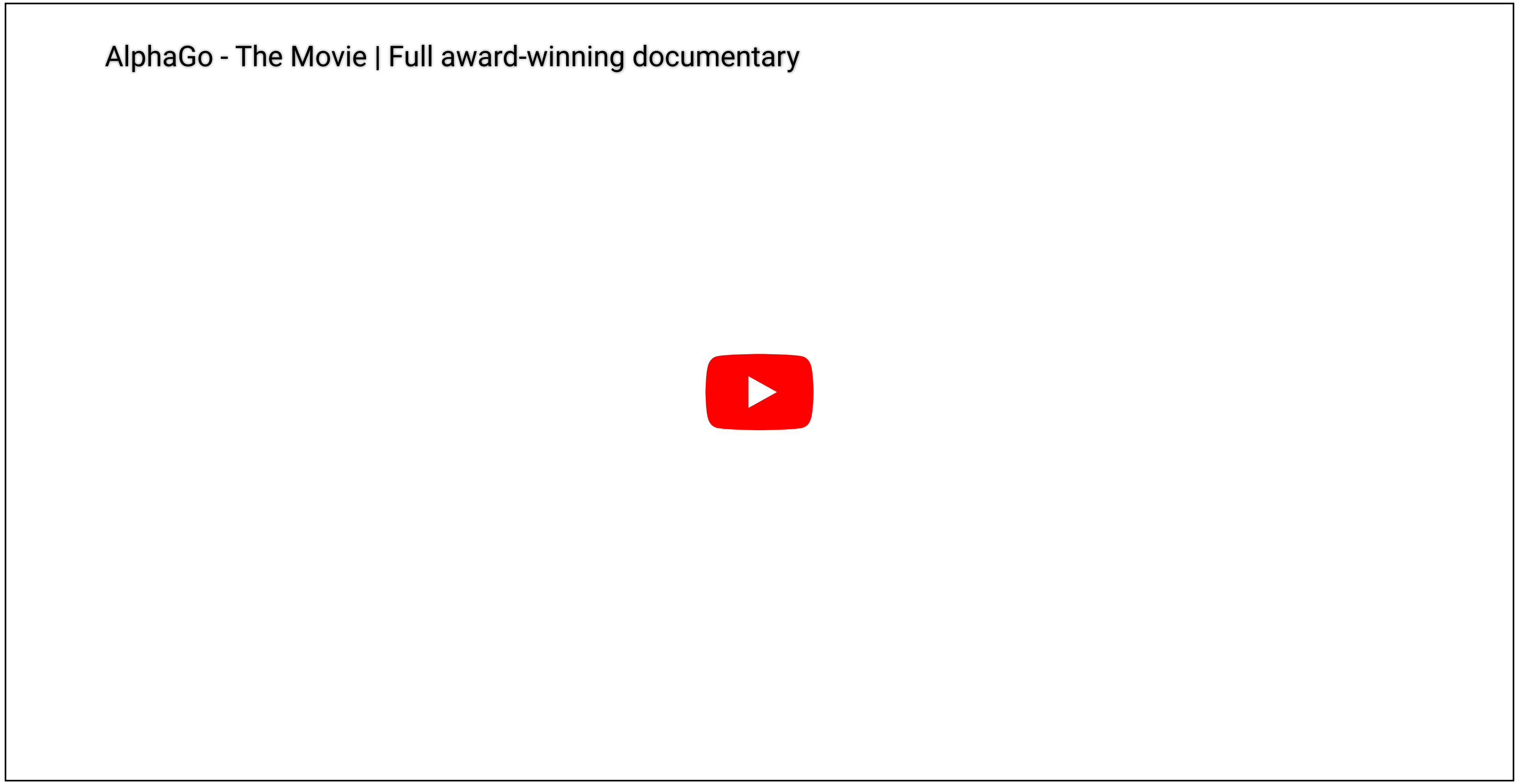
Needed a graphics card

A graphics processing unit (GPU)

"**4.2. Training on multiple GPUs** A single GTX 580 GPU has only 3GB of memory, which limits the maximum size of the networks that can be trained on it. It turns out that 1.2 million training examples are enough to train networks which are too big to fit on one GPU. Therefore we spread the net across two GPUs."

Source: Krizhevsky, Sutskever and Hinton (2017), *ImageNet Classification with Deep Convolutional Neural Networks*, Communications of the ACM

Lee Sedol plays AlphaGo (2016)



Deep Blue was a win for AI, AlphaGo a win for ML.

GANs

DALL-E

GPT

Code generation

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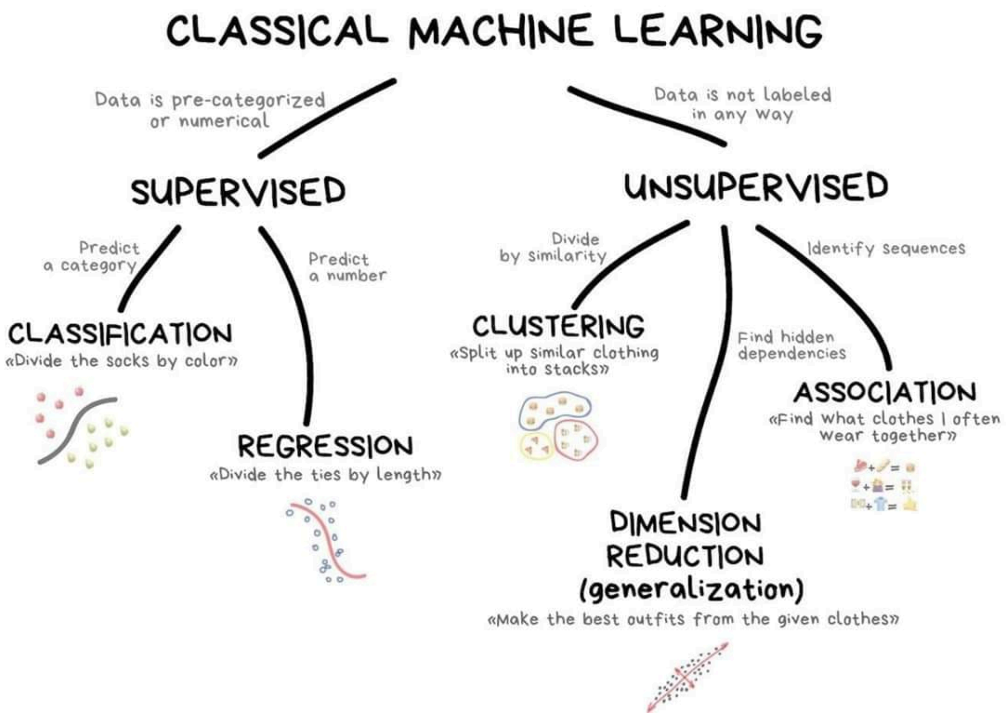
A taxonomy of problems



Machine learning categories in ACTL3142.

New ones:

- Reinforcement learning
- Semi-supervised learning
- Active learning

Source: Kaggle, Getting Started.

Supervised learning

The main focus of this course.

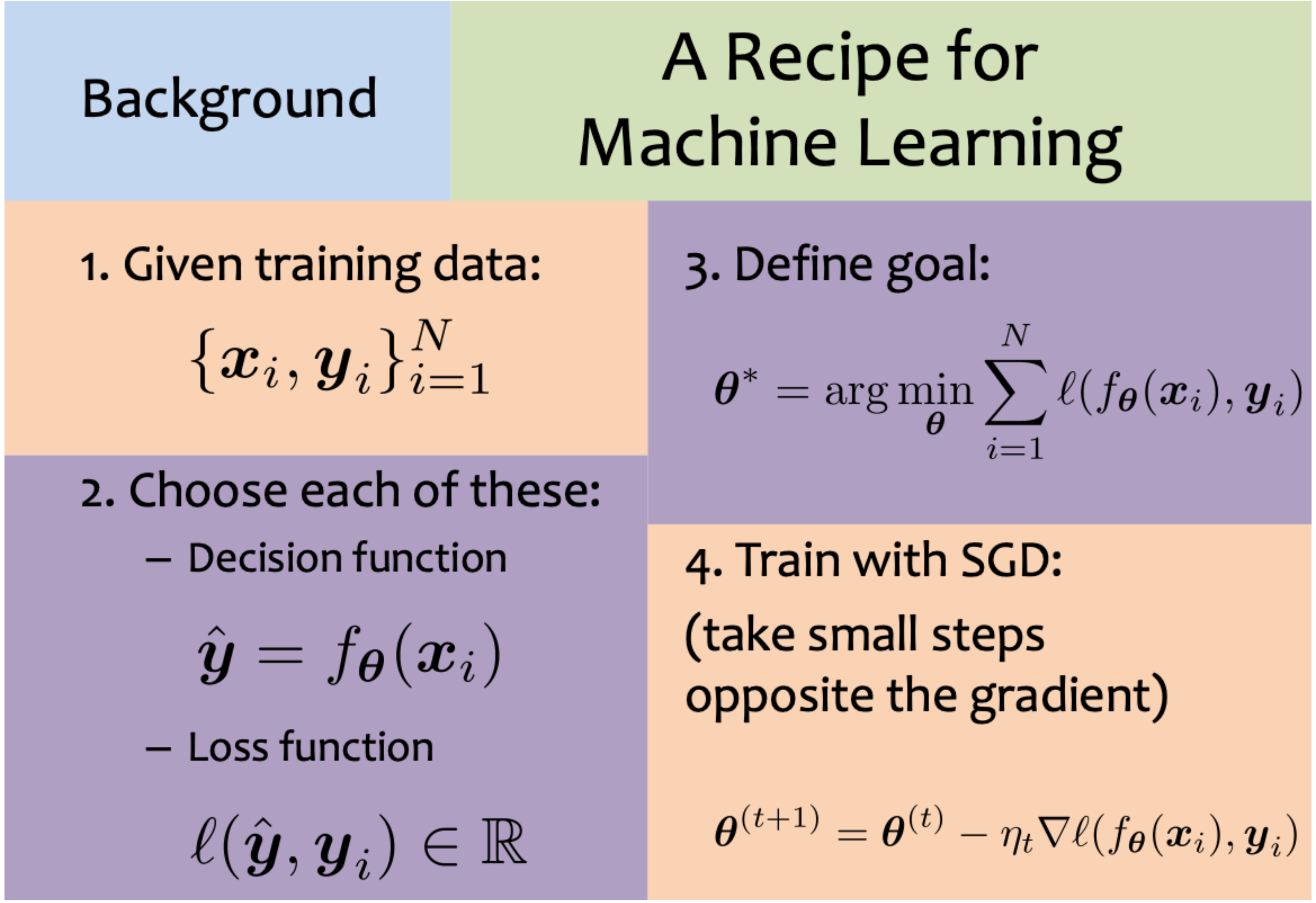
Regression

- Given policy $\hookrightarrow$ predict the rate of claims.
- Given policy $\hookrightarrow$ predict claim severity.
- Given a reserving triangle $\hookrightarrow$ predict future claims.

Classification

- Given a claim $\hookrightarrow$ classify as fraudulent or not.
- Given a customer $\hookrightarrow$ predict customer retention patterns.

Supervised learning: mathematically

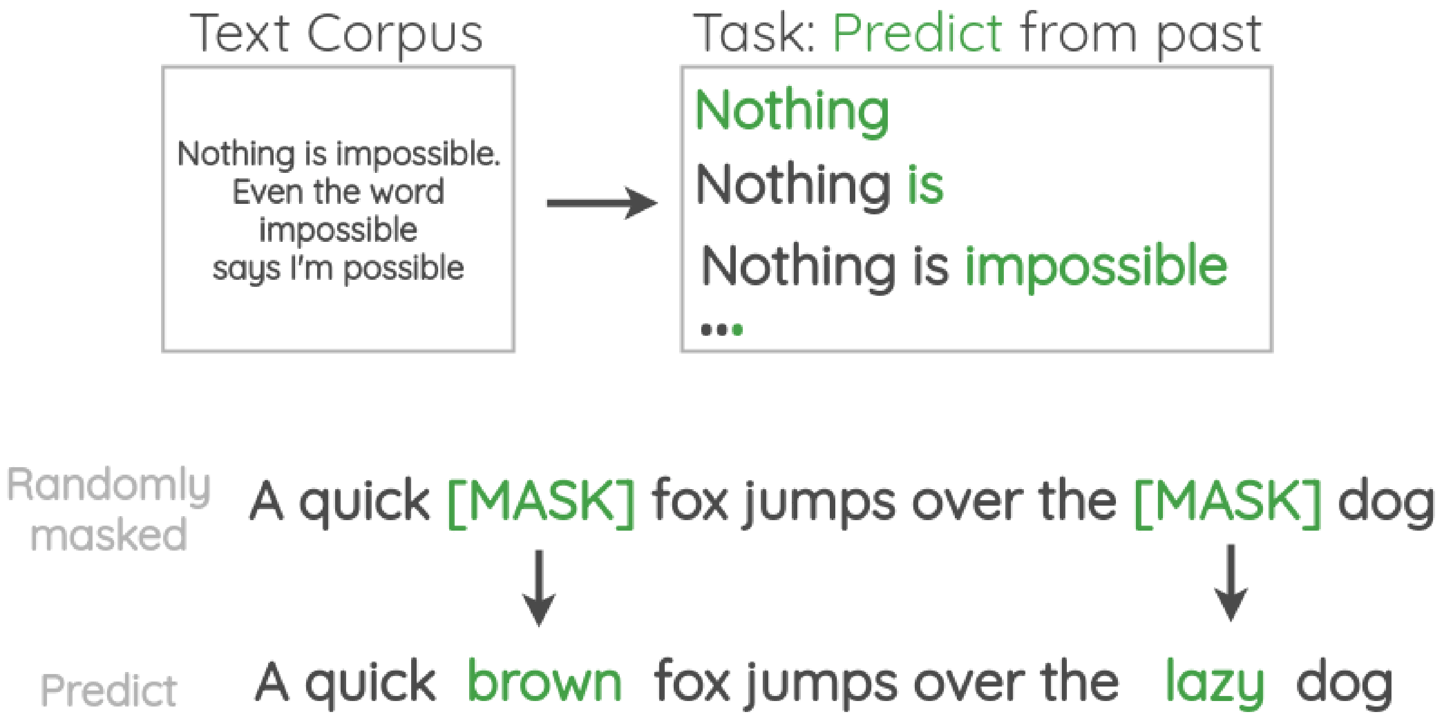


A recipe for supervised learning.

Source: Matthew Gormley (2021), Introduction to Machine Learning Lecture Slides, Slide 67.

Self-supervised learning

Data which 'labels itself'. Example: language model.

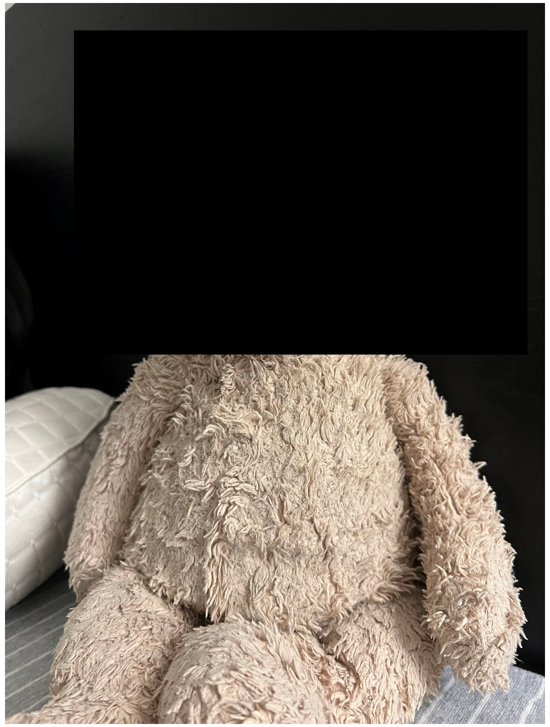


'Autoregressive' (e.g. GPT) versus 'masked' model (e.g. BERT).

Source: Amit Chaudhary (2020), Self Supervised Representation Learning in NLP.

Example: image inpainting

Original image



Randomly remove a part

Try to fill it in from context

Other examples: image super-resolution, denoising images.

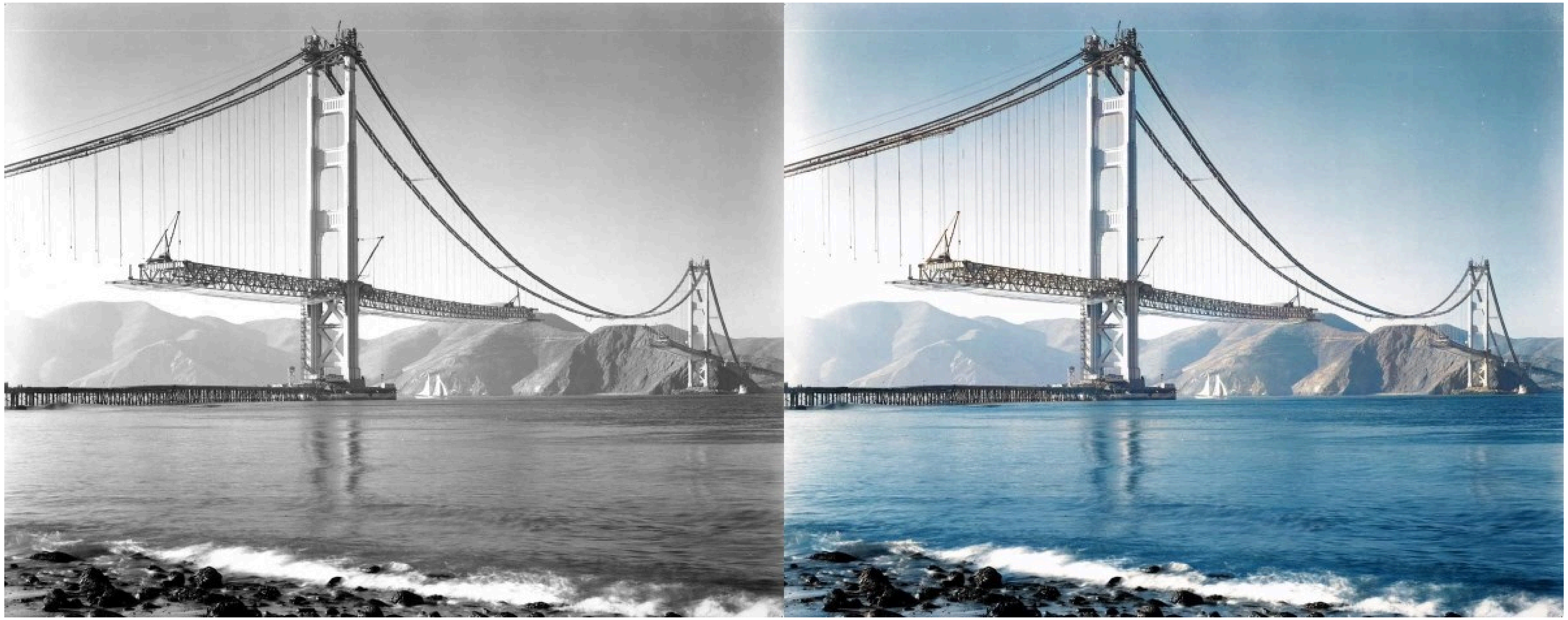
Cf. Liu et al. (2018), Image Inpainting for Irregular Holes using Partial Convolutions.

Example: Deoldify images #1

A deoldified version of the famous “Migrant Mother” photograph.

Source: Deoldify package.

Example: Deoldify images #2



A deoldified Golden Gate Bridge under construction.

Source: Deoldify package.

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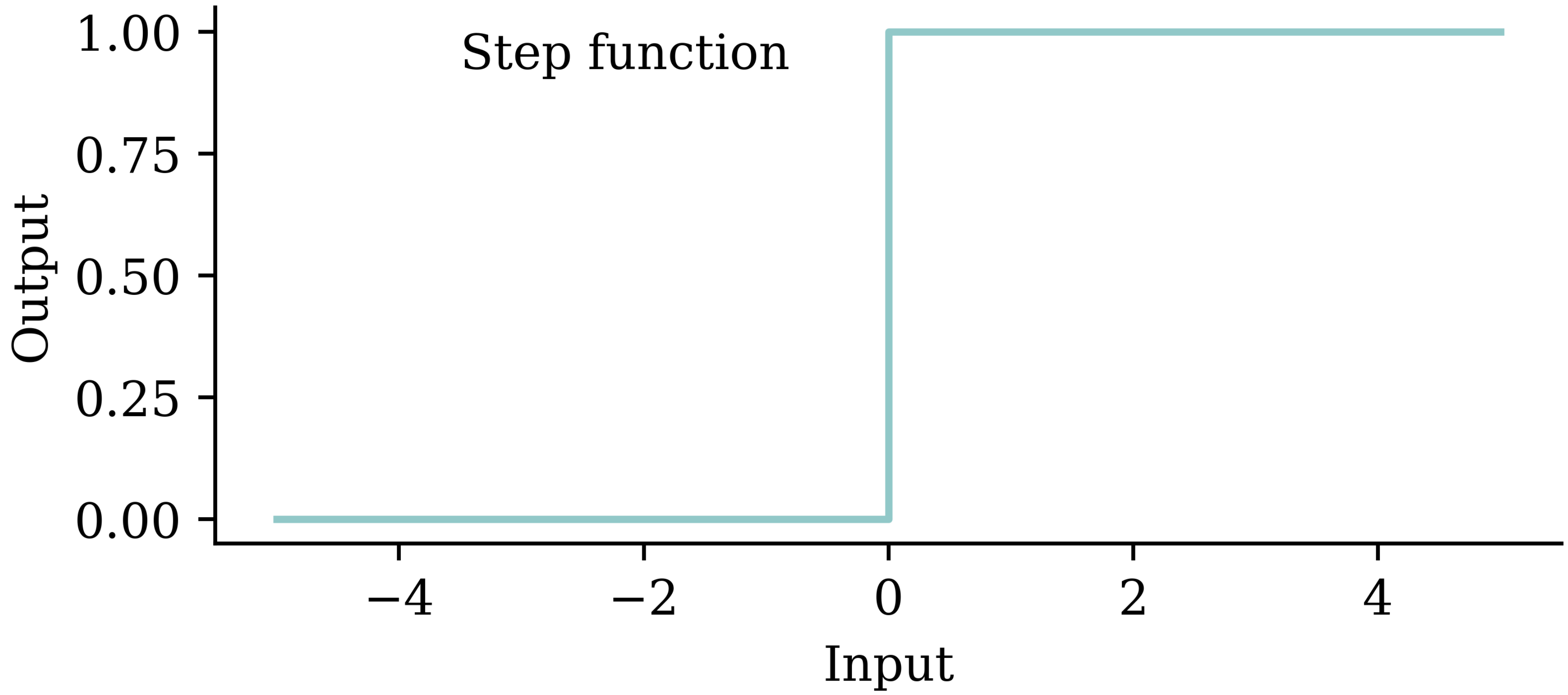
- **Neural Networks**

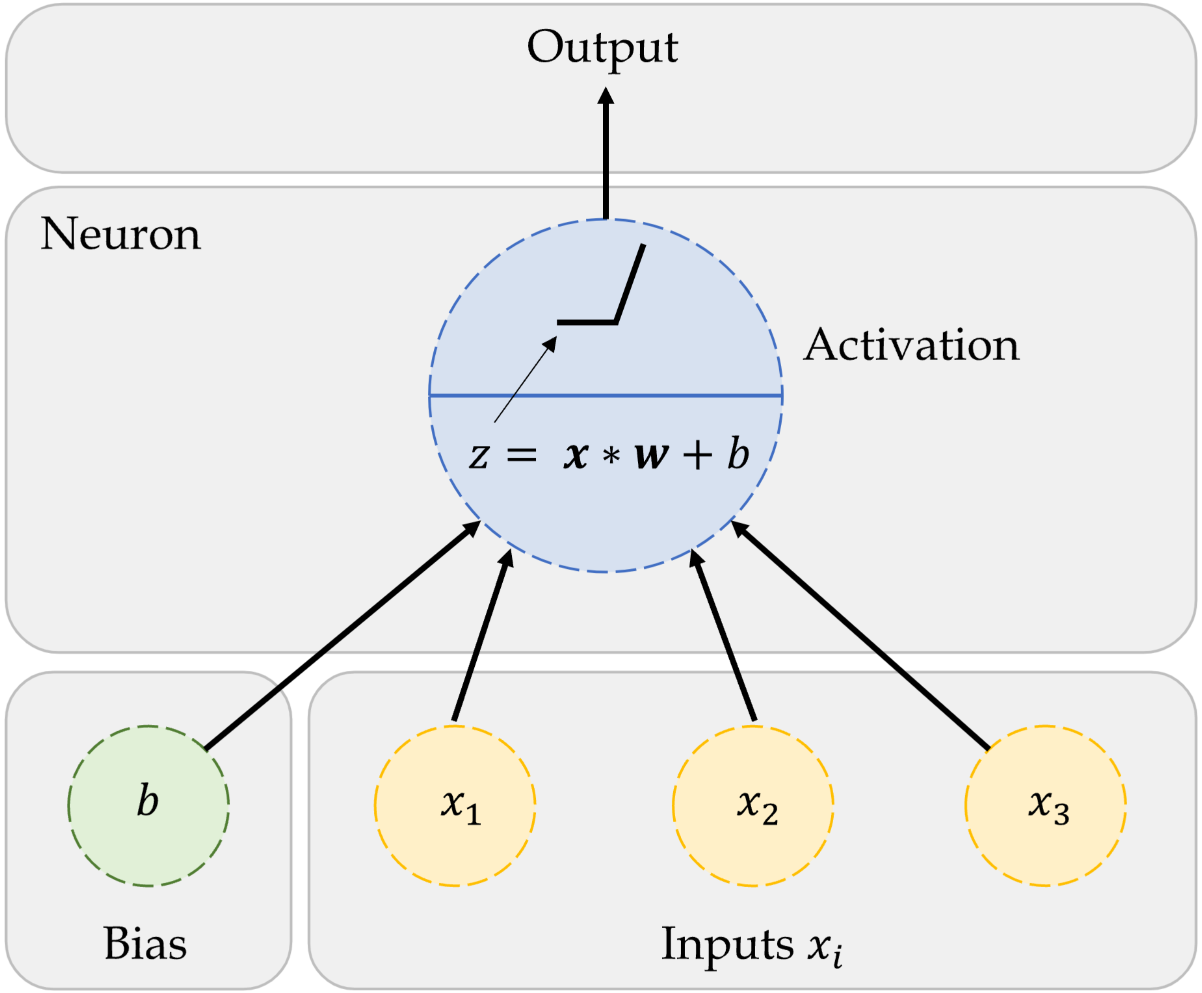
How do real neurons work?

2-Minute Neuroscience: The Neuron

A neuron ‘firing’



An artificial neuron



A neuron in a neural network with a ReLU activation.

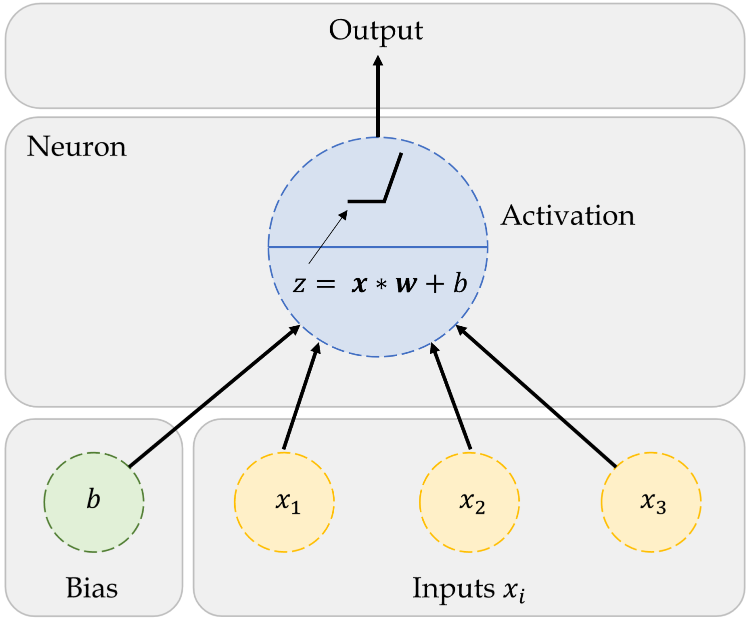
Source: Marcus Lautier (2022).

One neuron

$$
\begin{aligned}
z &= x_1 \times w_1 + \\
&\quad x_2 \times w_2 + \\
&\quad x_3 \times w_3 .
\end{aligned}
$$

$$
a = \begin{cases} z & \text{if } z > 0 \\ 0 & \text{if } z \leq 0 \end{cases}
$$

Here, x_1, x_2, x_3 is just some fixed data.



A neuron in a neural network with a ReLU activation.

The weights w_1, w_2, w_3 should be 'learned'.

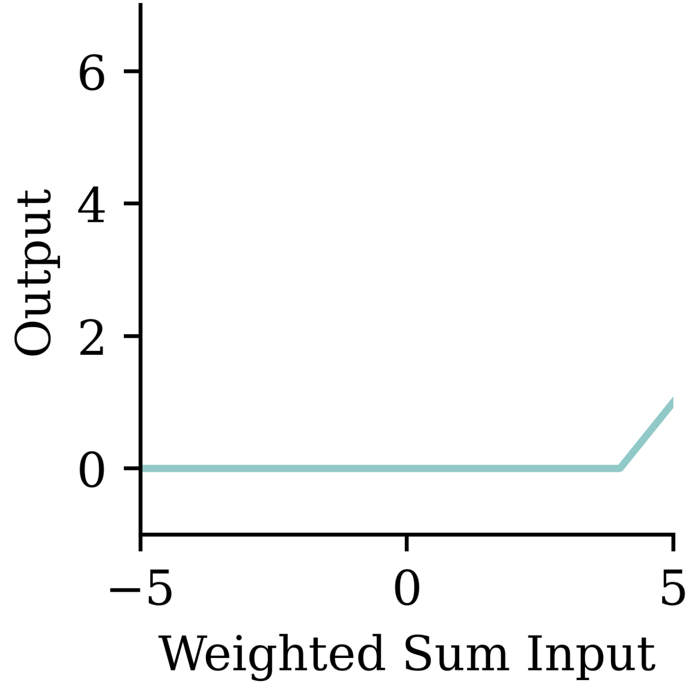
One neuron with bias

$$\begin{aligned} z &= x_1 \times w_1 + \\ &\quad x_2 \times w_2 + \\ &\quad x_3 \times w_3 + b. \end{aligned}$$

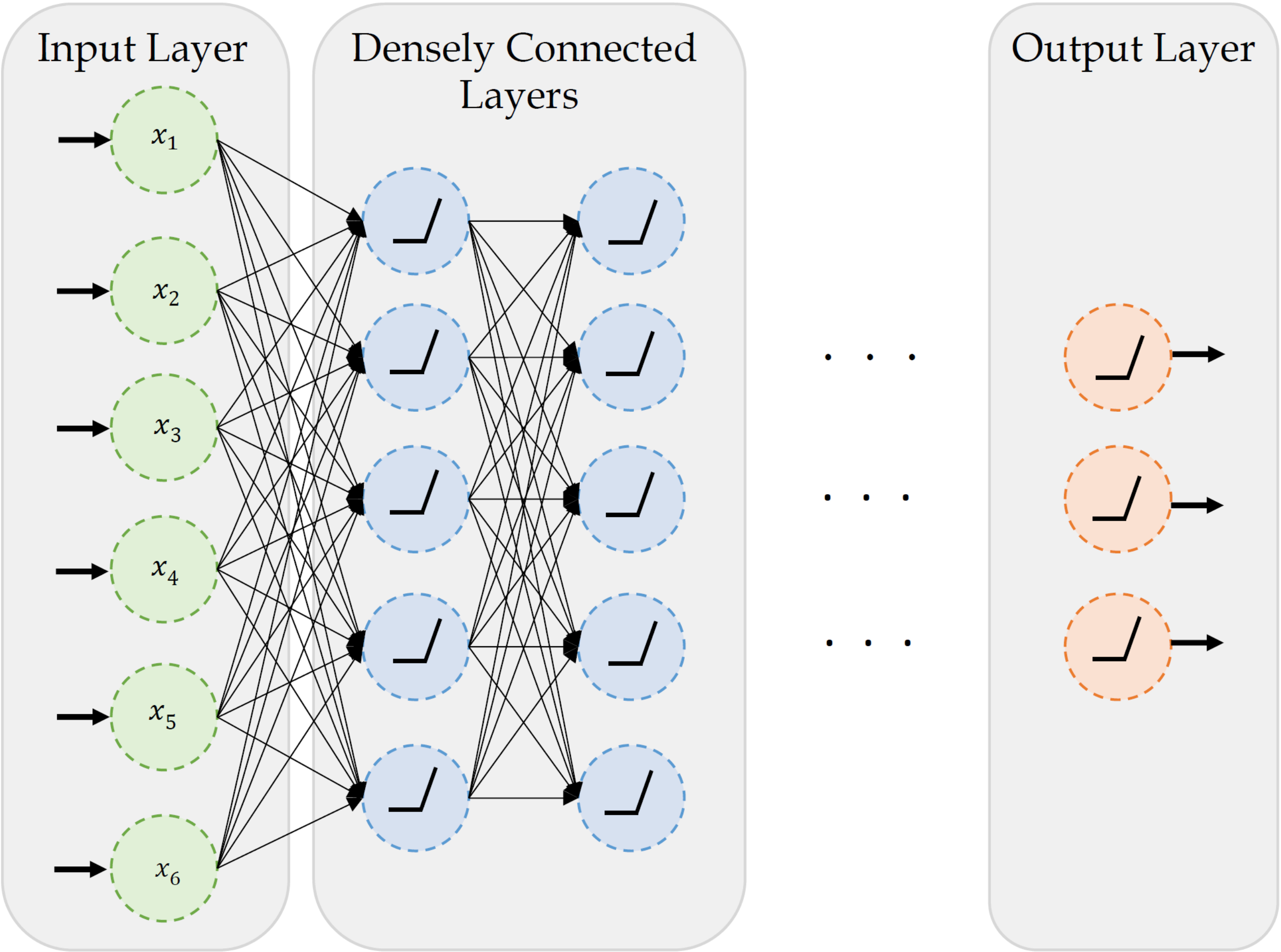
$$a = \begin{cases} z & \text{if } z > 0 \\ 0 & \text{if } z \leq 0 \end{cases}$$

The weights w_1, w_2, w_3 and bias b should be 'learned'.

Bias = -4 0 4



A basic neural network



A basic fully-connected/dense network.

Source: Marcus Lautier (2022).

Step-function activation

Perceptrons

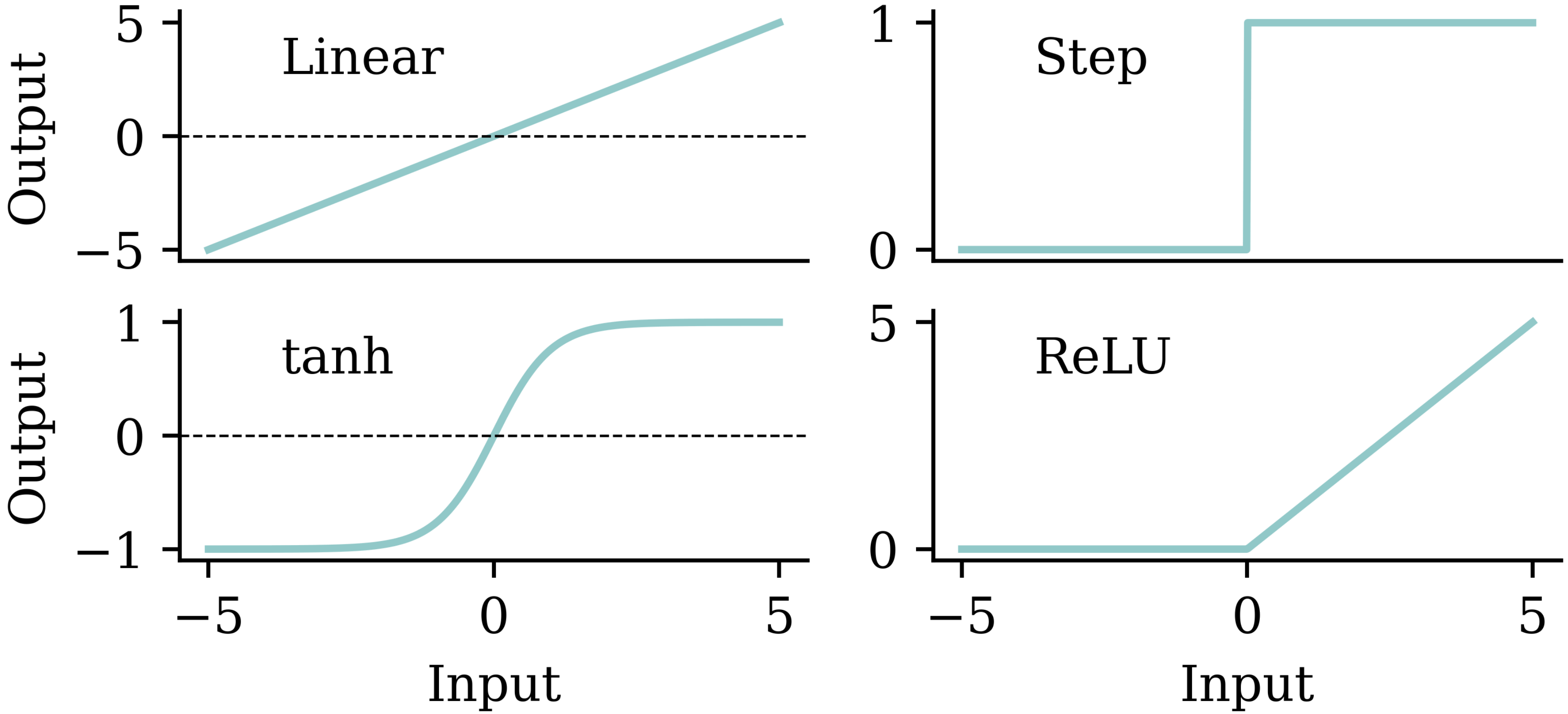
Brains and computers are binary, so make a perceptron with binary data. Seemed reasonable, impossible to train.

Modern neural network

Replace binary state with continuous state. Still rather slow to train.

> **Note**
>
> It's a neur**al** network made of neur**on**s, not a "neuron network".

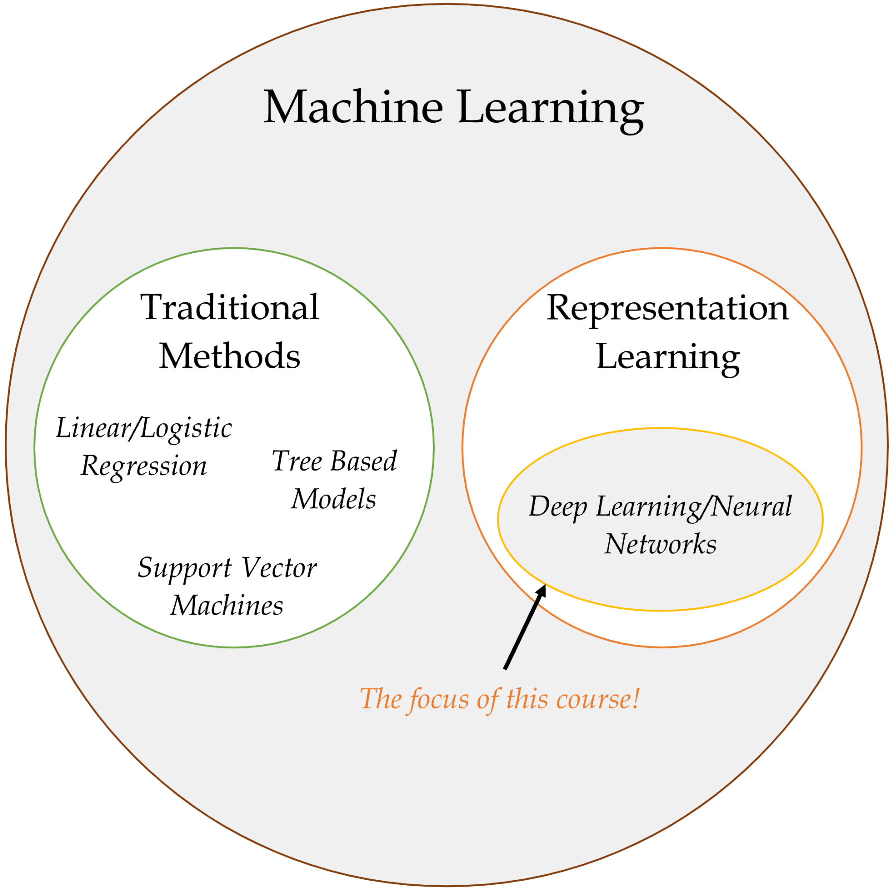
Try different activation functions

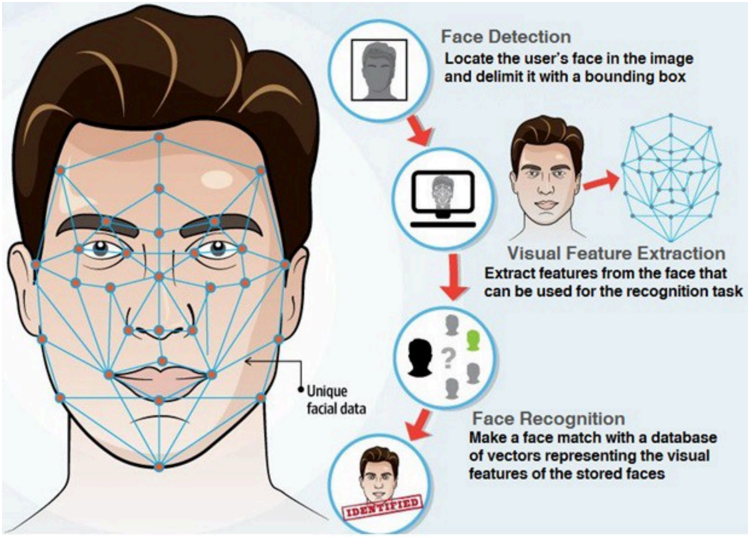


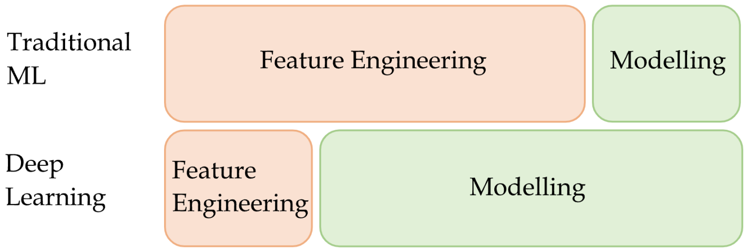
Flexible

> One can show that an MLP is a **universal approximator**, meaning it can model any suitably smooth function, given enough hidden units, to any desired level of accuracy (Hornik 1991). One can either make the model be "wide" or "deep"; the latter has some advantages…

Feature engineering







The deep learning hammer

Deep learning is not always the answer!

The map of data science.

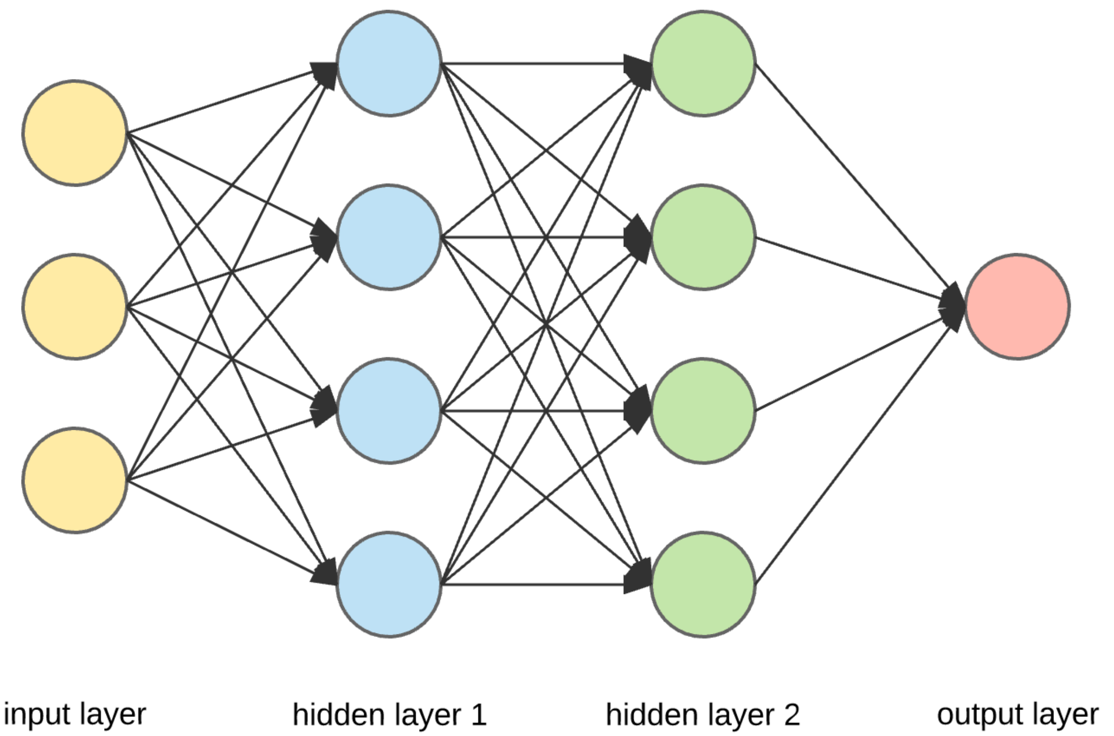
Source: Serge Masis (2022), LinkedIn post.

Quiz

In this ANN, how many of the following are there:

- features,
- targets,
- weights,
- biases, and
- parameters?

What is the depth?



An artificial neural network.

Source: Dertat (2017), *Applied Deep Learning - Part 1: Artificial Neural Networks*, Medium.

Package Versions

```python
from watermark import watermark
print(watermark(python=True, packages="keras,matplotlib,numpy,pandas,seaborn,scipy,torch
```

```
Python implementation: CPython
Python version       : 3.11.9
IPython version      : 8.24.0

keras     : 3.3.3
matplotlib: 3.9.0
numpy     : 1.26.4
pandas    : 2.2.2
seaborn   : 0.13.2
scipy     : 1.11.0
torch     : 2.3.0
tensorflow: 2.16.1
tf_keras  : 2.16.0
```

Glossary

- activations, activation function
- artificial neural network
- biases (in neurons)
- classification problem
- deep network, network depth
- dense or fully-connected layer
- feed-forward neural network
- labelled/unlabelled data
- machine learning
- neural network architecture
- perceptron
- ReLU
- representation learning
- sigmoid activation function
- targets
- training/test split
- weights (in a neuron)