Artificial Intelligence

ACTL3143 & ACTL5111 Deep Learning for Actuaries

Patrick Laub

Lecture Outline

- **Artificial Intelligence**
- Deep Learning Successes (Images)
- Deep Learning Successes (Text)
- Classifying Machine Learning Tasks
- Neural Networks

Different goals of AI

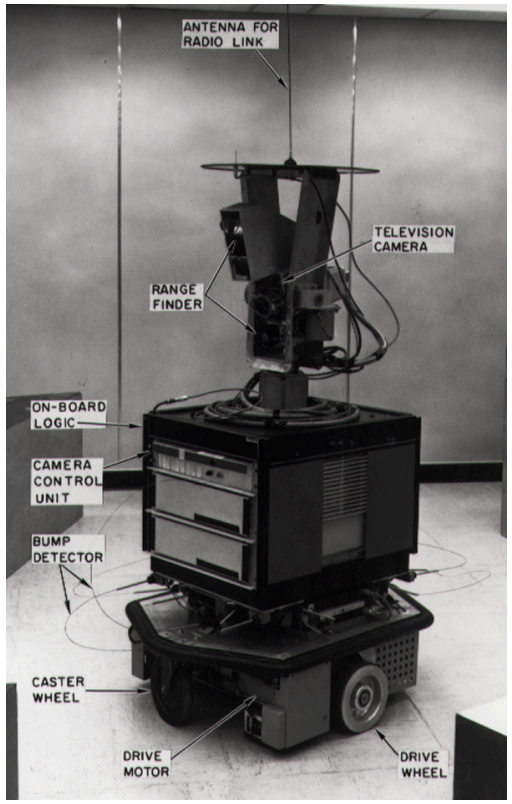
Artificial intelligence describes an agent which is capable of:

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

Shakey the Robot: The First Robot to Embody Artificial Intel...

Source: Wikipedia page for the Shakey Project

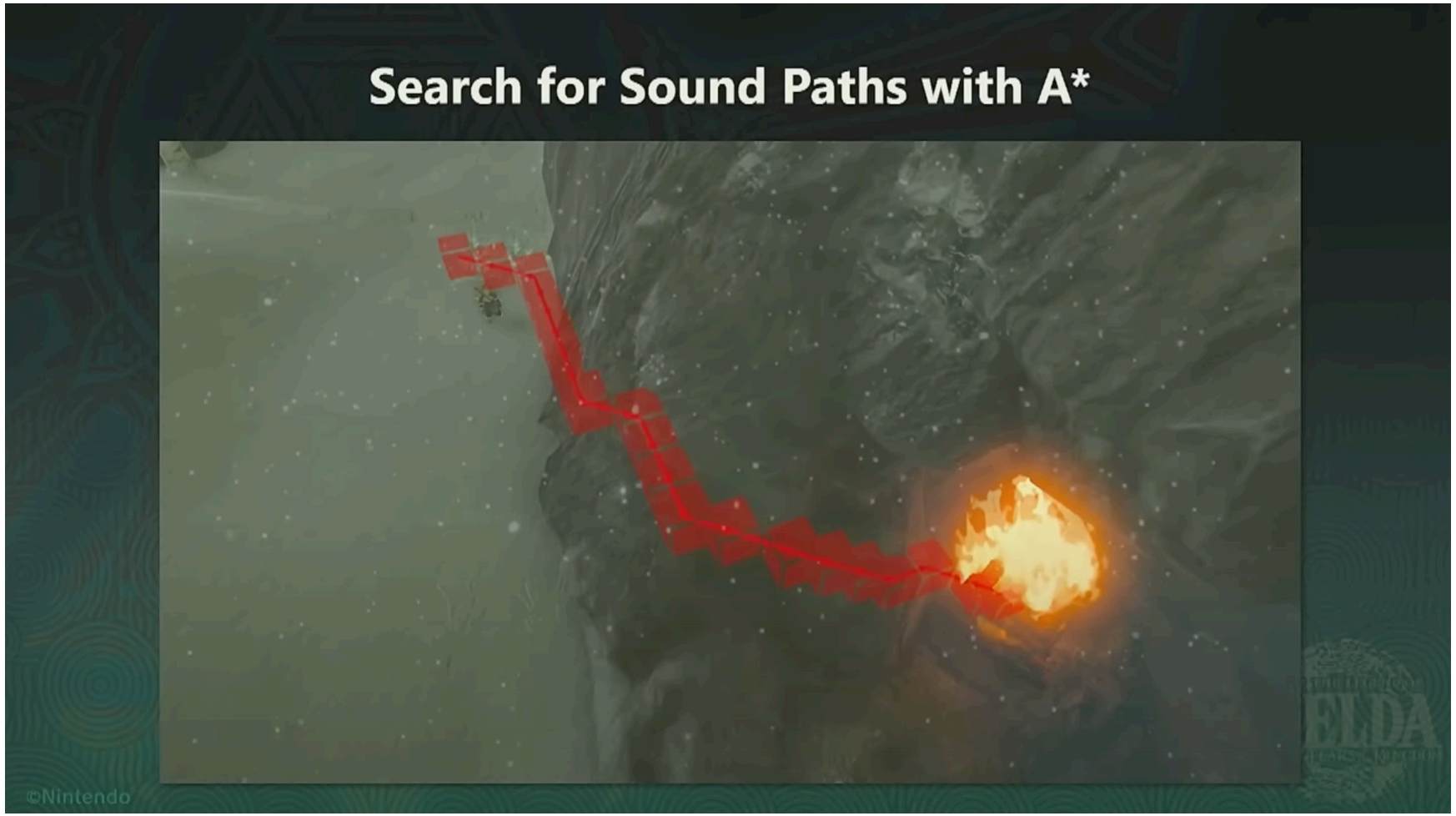
Route-finding I

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.

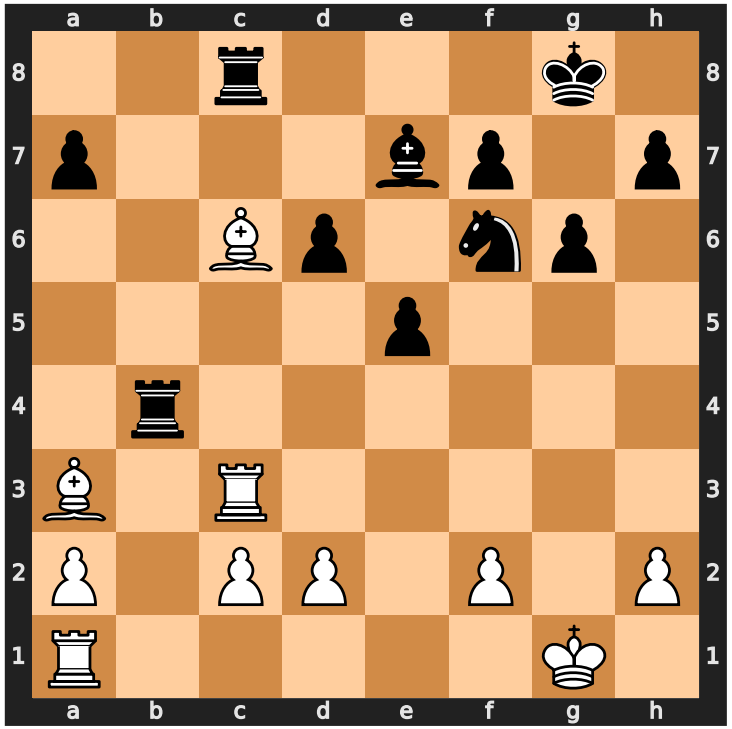
Route-finding II



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

Evaluating a chess game I

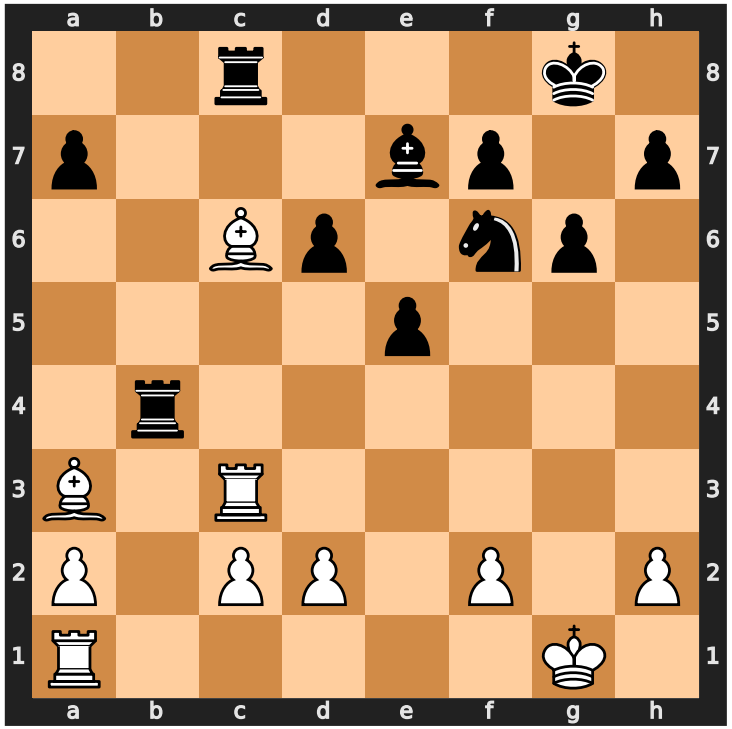
Who's winning this game?



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

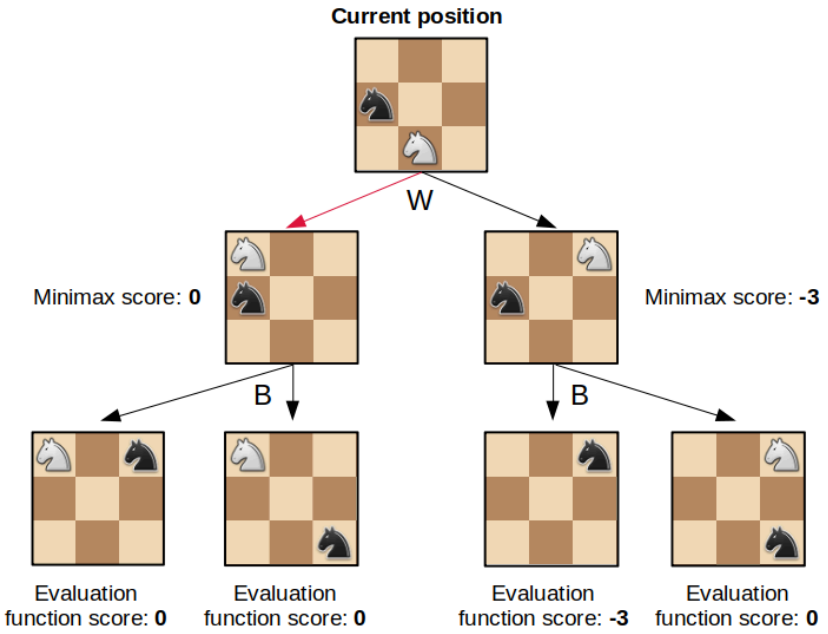
Evaluating a chess game II

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

The minimax algorithm



The minimax algorithm for chess.

```
function minimax(position, depth, maximizingPlayer)
   if depth == 0 or game over in position
      return static evaluation of position

   if maximizingPlayer
      maxEval = -infinity
      for each child of position
         eval = minimax(child, depth - 1, false)
         maxEval = max(maxEval, eval)
      return maxEval

   else
      minEval = +infinity
      for each child of position
         eval = minimax(child, depth - 1, true)
         minEval = min(minEval, eval)
      return minEval
```

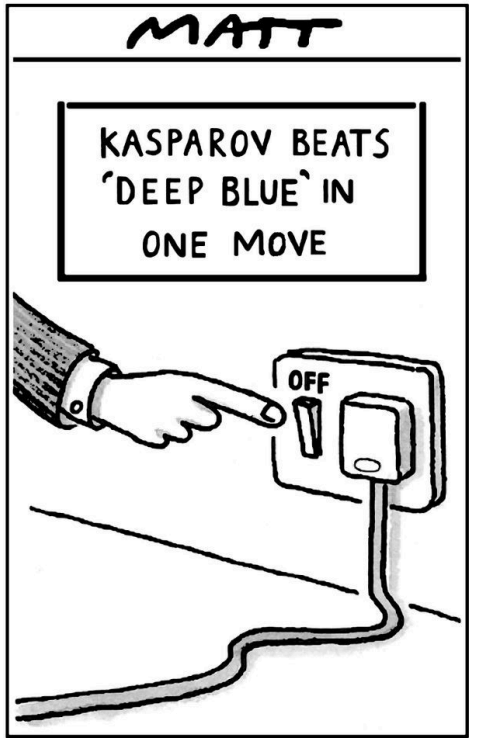
Pseudocode for the minimax algorithm.

Source: codeRtime, Programming a simple minimax chess engine in R, and Sebastian Lague (2018), Algorithms Explained – minimax and alpha-beta pruning.

Chess

Deep Blue (1997)

Gary Kasparov playing Deep Blue.



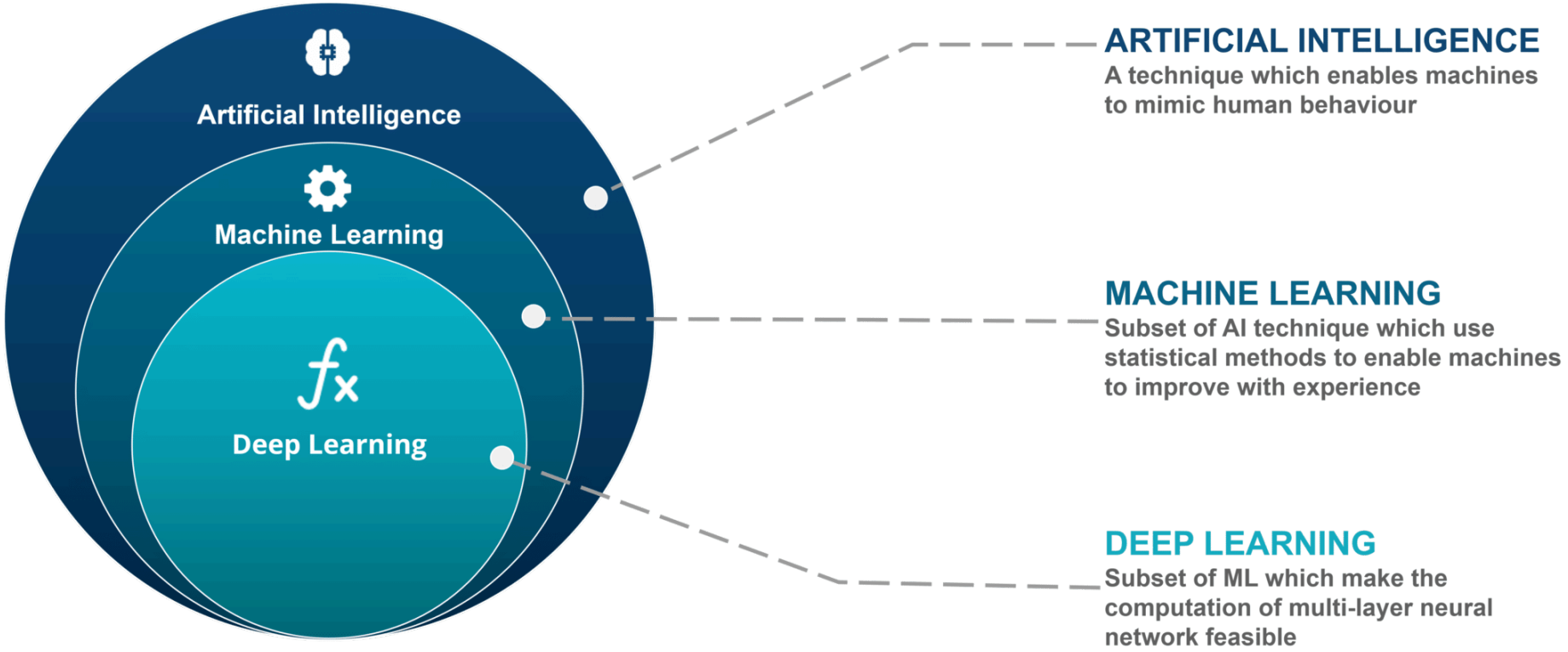
Cartoon of the match.

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

Machine Learning

Tried *making a computer smart*, too hard!

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

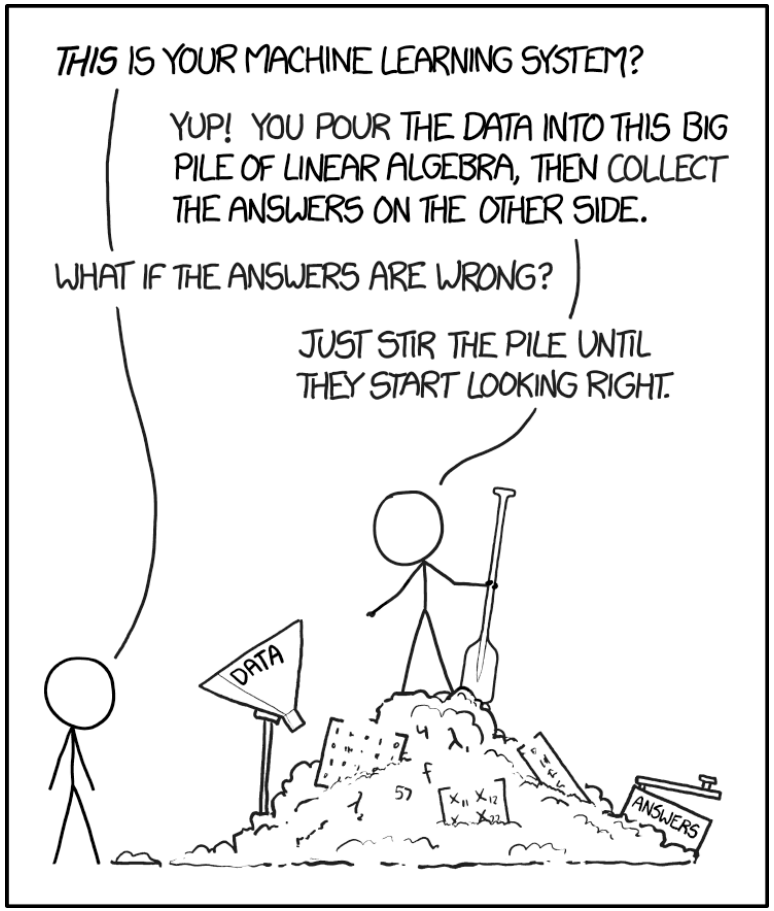


The Venn diagram of Artificial Intelligence, Machine Learning, and Deep Learning.

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.

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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?

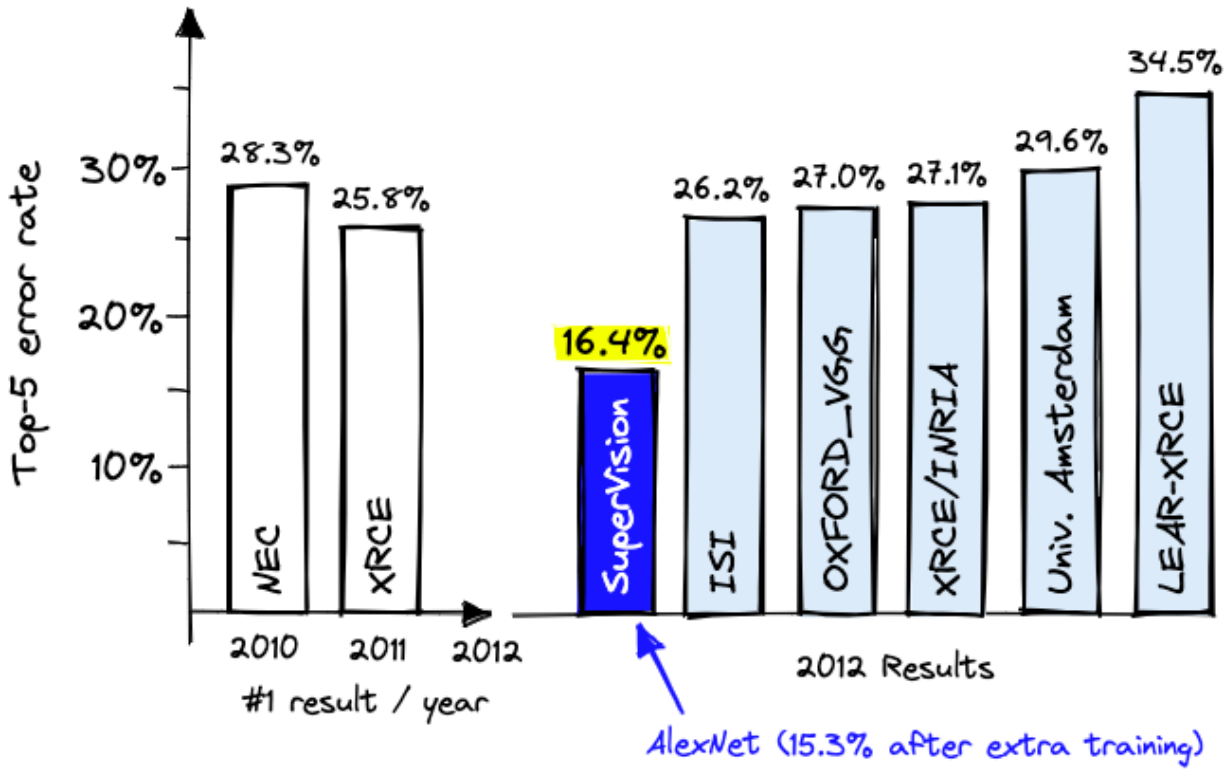
Options:

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.

How were the images labelled?

The original ‘mechanical turk’ (1770)

“Two years later, the first version of ImageNet was released with 12 million images structured and labeled in line with the WordNet ontology. If one person had annotated one image/minute and did nothing else in those two years (including sleeping or eating), it would have taken 22 years and 10 months.

To do this in under two years, Li turned to Amazon Mechanical Turk, a crowdsourcing platform where anyone can hire people from around the globe to perform tasks cost-effectively.”

Sources: Editors of Encyclopaedia Britannica, The Mechanical Turk: AI Marvel or Parlor Trick?, and 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)

My deep learning PC

"**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.

Lee Sedol playing AlphaGo AI

I highly recommend this documentary about the event.

Source: Patrick House (2016), AlphaGo, Lee Sedol, and the Reassuring Future of Humans and Machines, New Yorker article.

Generative Adversarial Networks (2014)

https://thispersondoesnotexist.com/

A GAN-generated face

A GAN-generated face

Diffusion models

Painting of avocado skating while wearing a hoodie

A surrealist painting of an alpaca studying for an exam

Source: Dall-E 2 images, prompts by ACTL3143 students in 2022.

Dall-E 2 (2022) vs Dall-E 3 (2023)

Same prompt: “A beautiful calm photorealistic view of an waterside metropolis that has been neglected for hundreds of years and is overgrown with nature”

Dall-E 2

Dall-E 3

Dall-E 3 rewrites it as: “Photo of a once-majestic metropolis by the water, now abandoned for centuries. The city’s skyscrapers and buildings are cloaked in thick green vines…”

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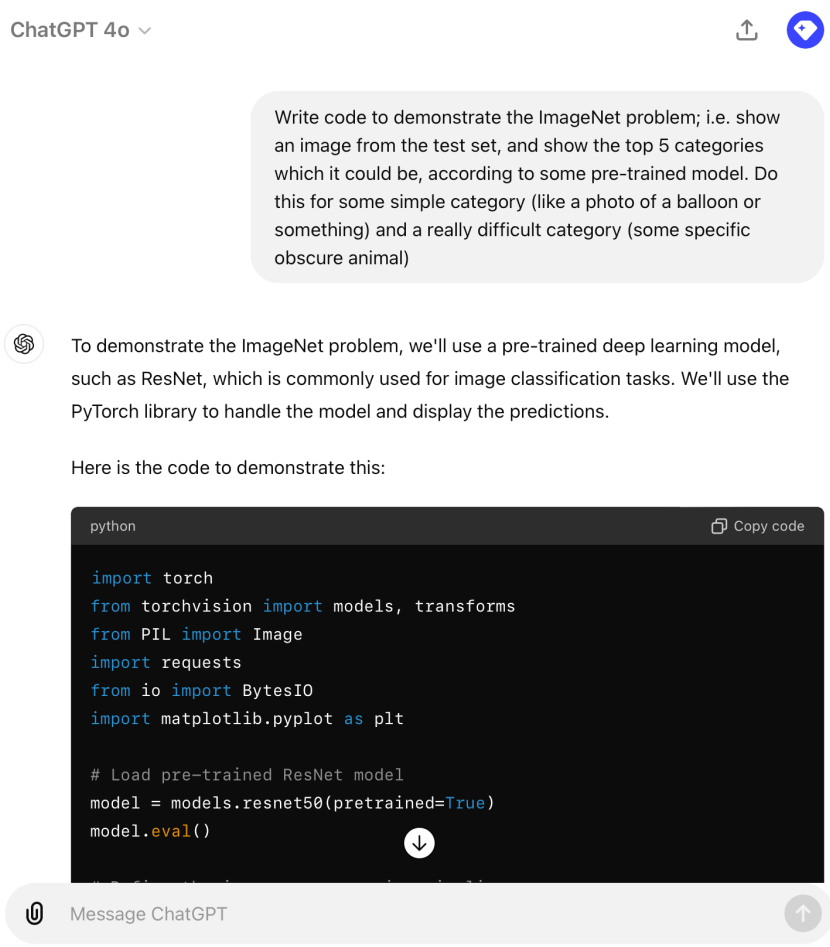
GPT



AI predictions in the classification demo were from GPT code.

Source: ChatGPT conversation.

Homework Get ChatGPT to:

- generate images
- translate code
- explain code
- run code
- analyse a dataset
- critique code
- critique writing
- voice chat with you

Compare to Copilot.

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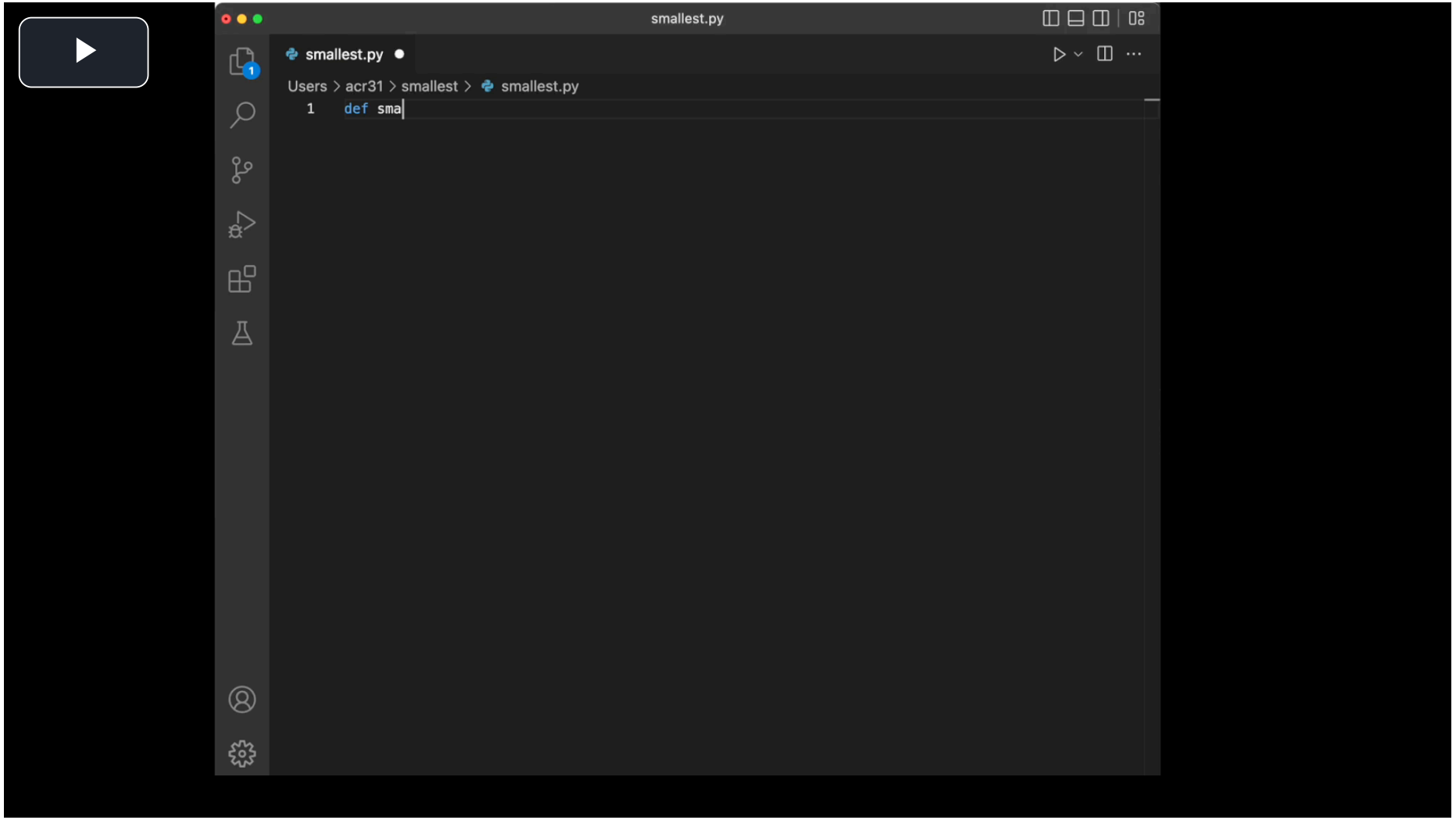
Code generation (GitHub Copilot)



Source: GitHub Blog

Students get Copilot for free

Use a free trial then sign up for free education account

A student post from last year:

> I strongly recommend taking a photo holding up your Academic Statement to your phone's front facing camera when getting verified for the student account on GitHub. No other method of taking/uploading photo proofs worked for me. Furthermore, I had to make sure the name on the statement matched my profile exactly and also had to put in a bio.
>
> Good luck with this potentially annoying process!

Homework It's a slow process, so get this going early.

Source: GitHub Education for Students

Programmers are increasingly using AI

	I use it	I tried it, but don't use it now	I don't use it
ChatGPT	77%	20%	3%
GitHub Copilot	46%	33%	21%
Midjourney	26%	50%	25%
Visual Studio IntelliCode	26%	15%	59%
OpenAI DALL-E	21%	42%	37%
Dream Studio (Stable Diffusion)	17%	21%	62%

Question: What is your experience with the following AI tools?

Source: JetBrains, The State of Developer Ecosystem 2023.

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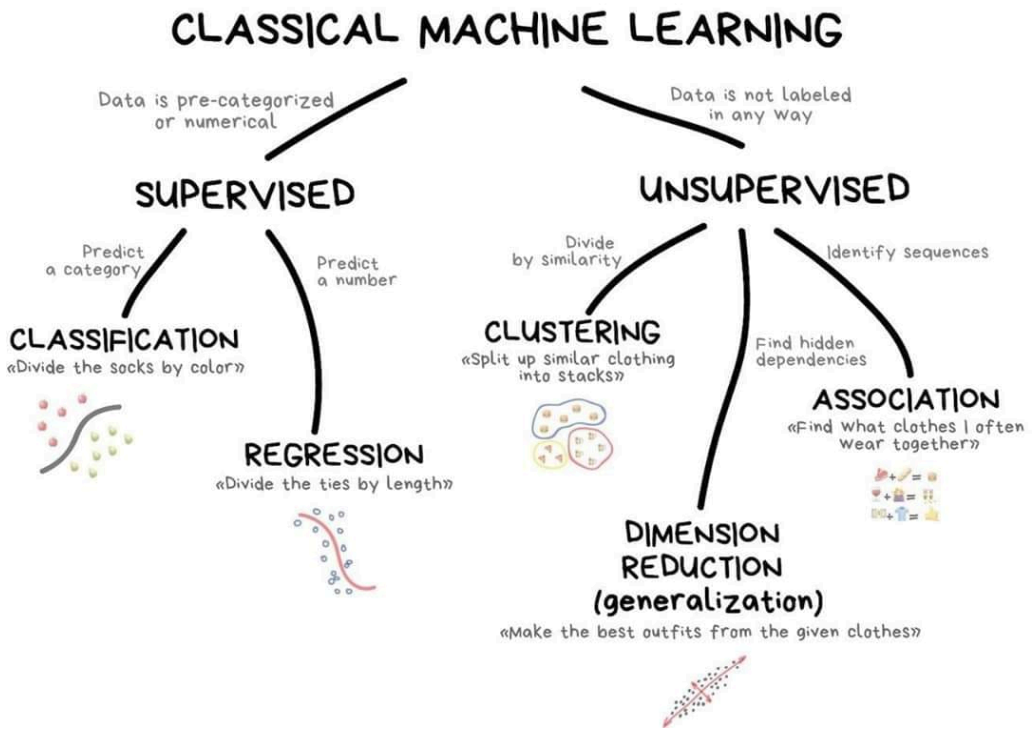
A taxonomy of problems



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

Background

A Recipe for Machine Learning

1. Given training data:

$$\{\boldsymbol{x}_i, \boldsymbol{y}_i\}_{i=1}^{N}$$

2. Choose each of these:
   - Decision function

$$\hat{\boldsymbol{y}} = f_{\boldsymbol{\theta}}(\boldsymbol{x}_i)$$

   - Loss function

$$\ell(\hat{\boldsymbol{y}}, \boldsymbol{y}_i) \in \mathbb{R}$$

3. Define goal:

$$\boldsymbol{\theta}^* = \arg\min_{\boldsymbol{\theta}} \sum_{i=1}^{N} \ell(f_{\boldsymbol{\theta}}(\boldsymbol{x}_i), \boldsymbol{y}_i)$$

4. Train with SGD:

(take small steps opposite the gradient)

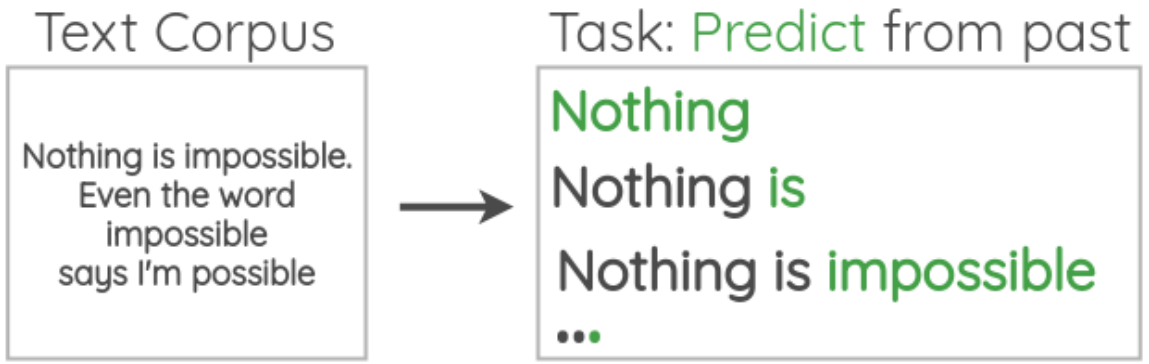
$$\boldsymbol{\theta}^{(t+1)} = \boldsymbol{\theta}^{(t)} - \eta_t \nabla \ell(f_{\boldsymbol{\theta}}(\boldsymbol{x}_i), \boldsymbol{y}_i)$$

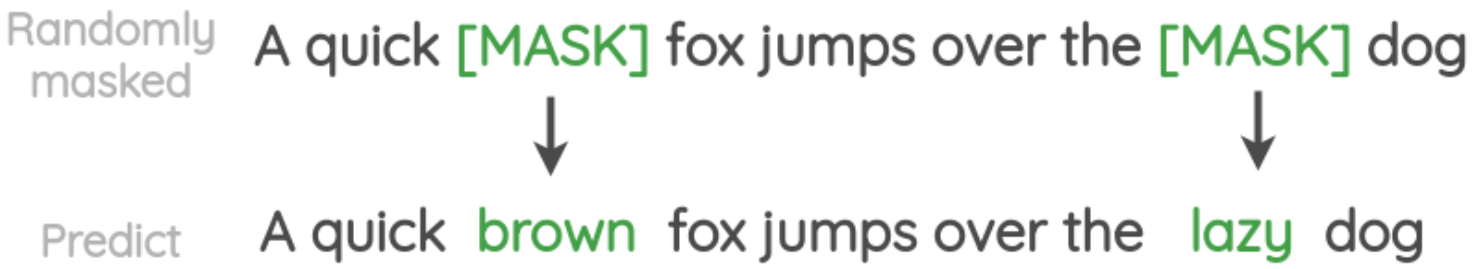
A recipe for supervised learning.

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

Self-supervised learning

Data which ‘labels itself’. Example: language model.



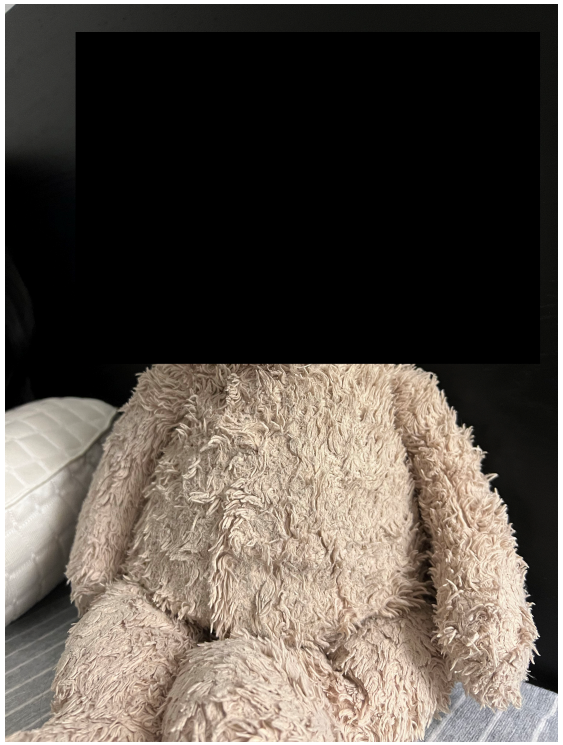


‘Autoregressive’ (e.g. GPT) versus ‘masked’ model (e.g. BERT).

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.

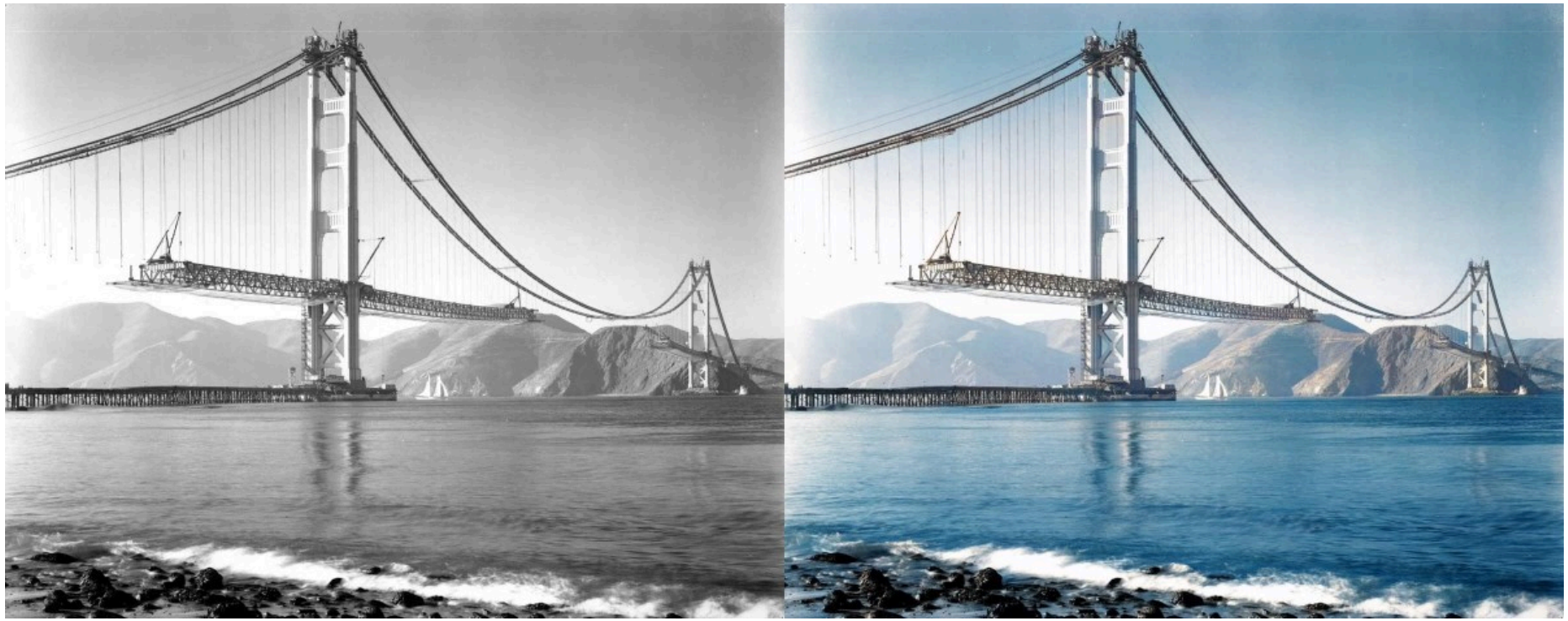
See Liu et al. (2018), Image Inpainting for Irregular Holes using Partial Convolutions.

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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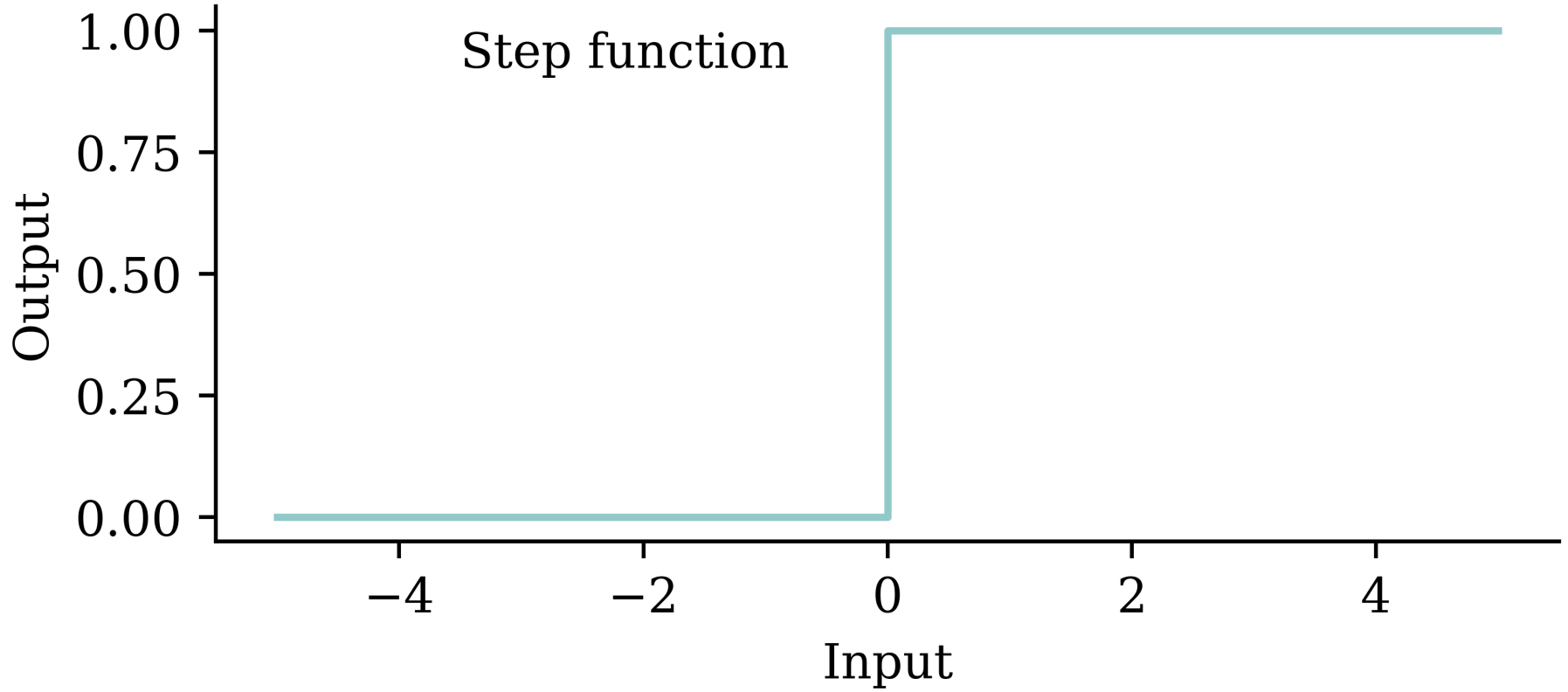
- **Neural Networks**

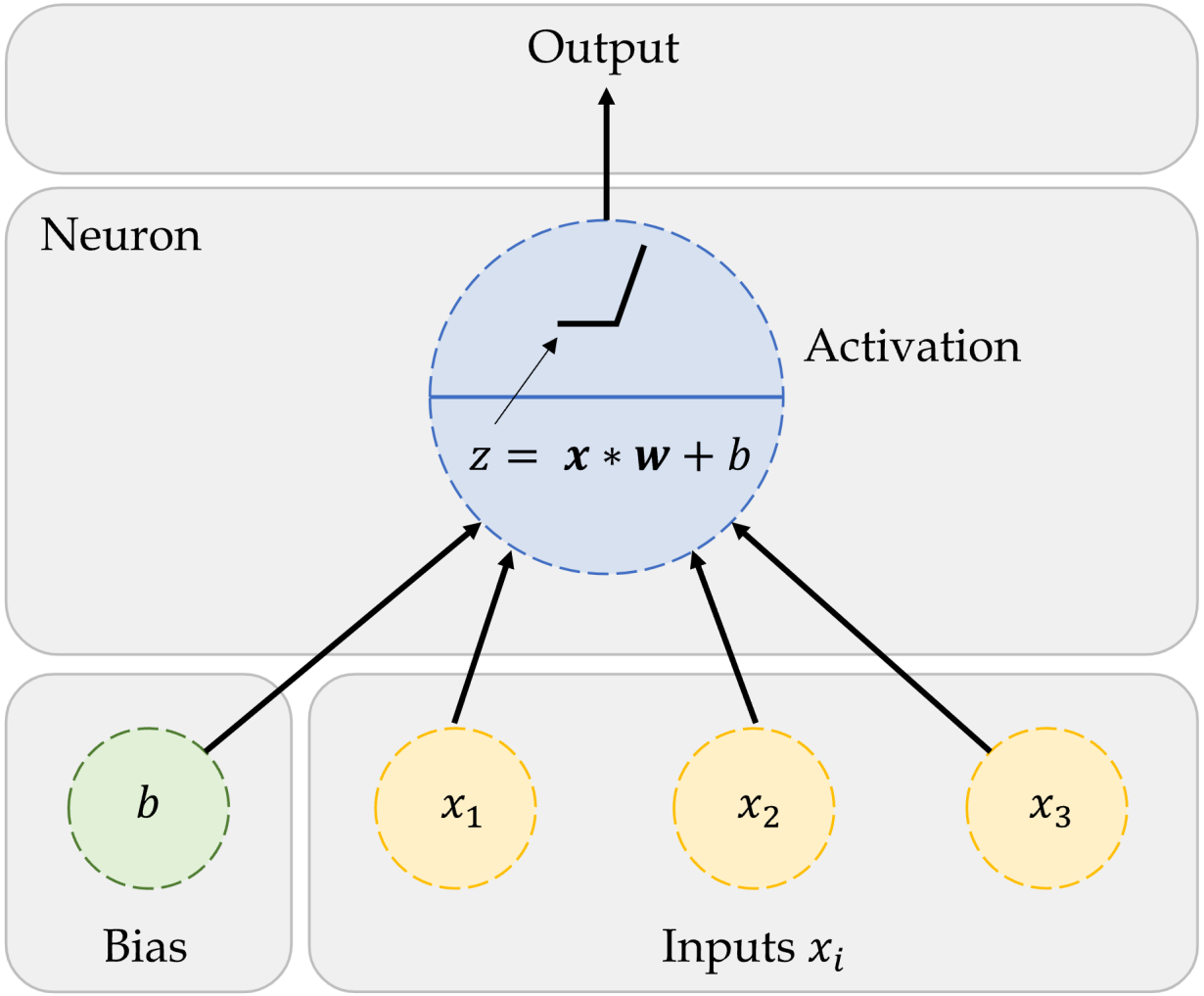
How do real neurons work?

2-Minute Neuroscience: The Neuron

A neuron ‘firing’



An artificial neuron



A neuron in a neural network with a ReLU activation.

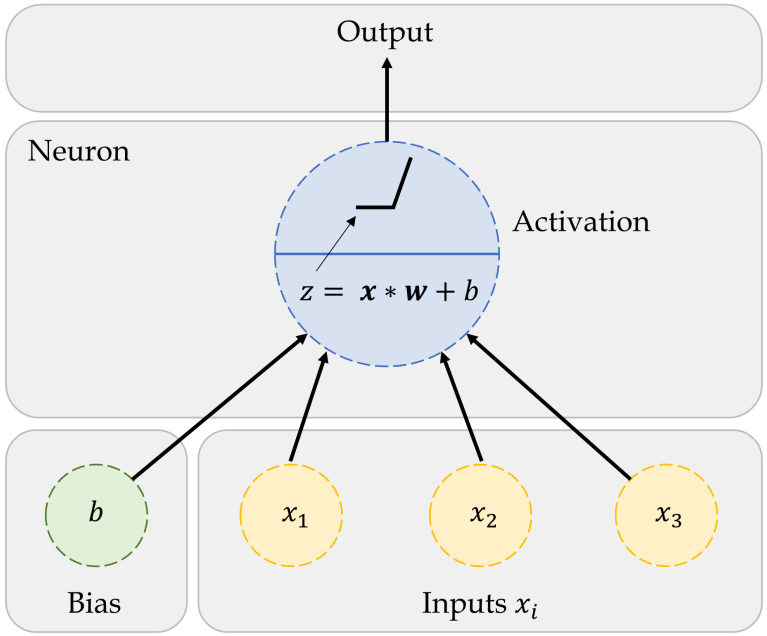
Source: Marcus Lautier (2022).

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'.

Source: Marcus Lautier (2022).

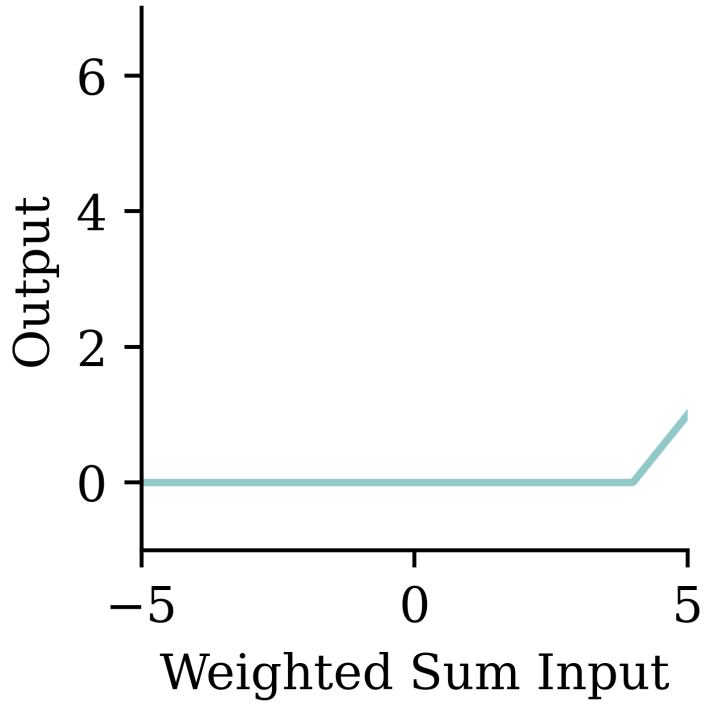
One neuron with bias

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

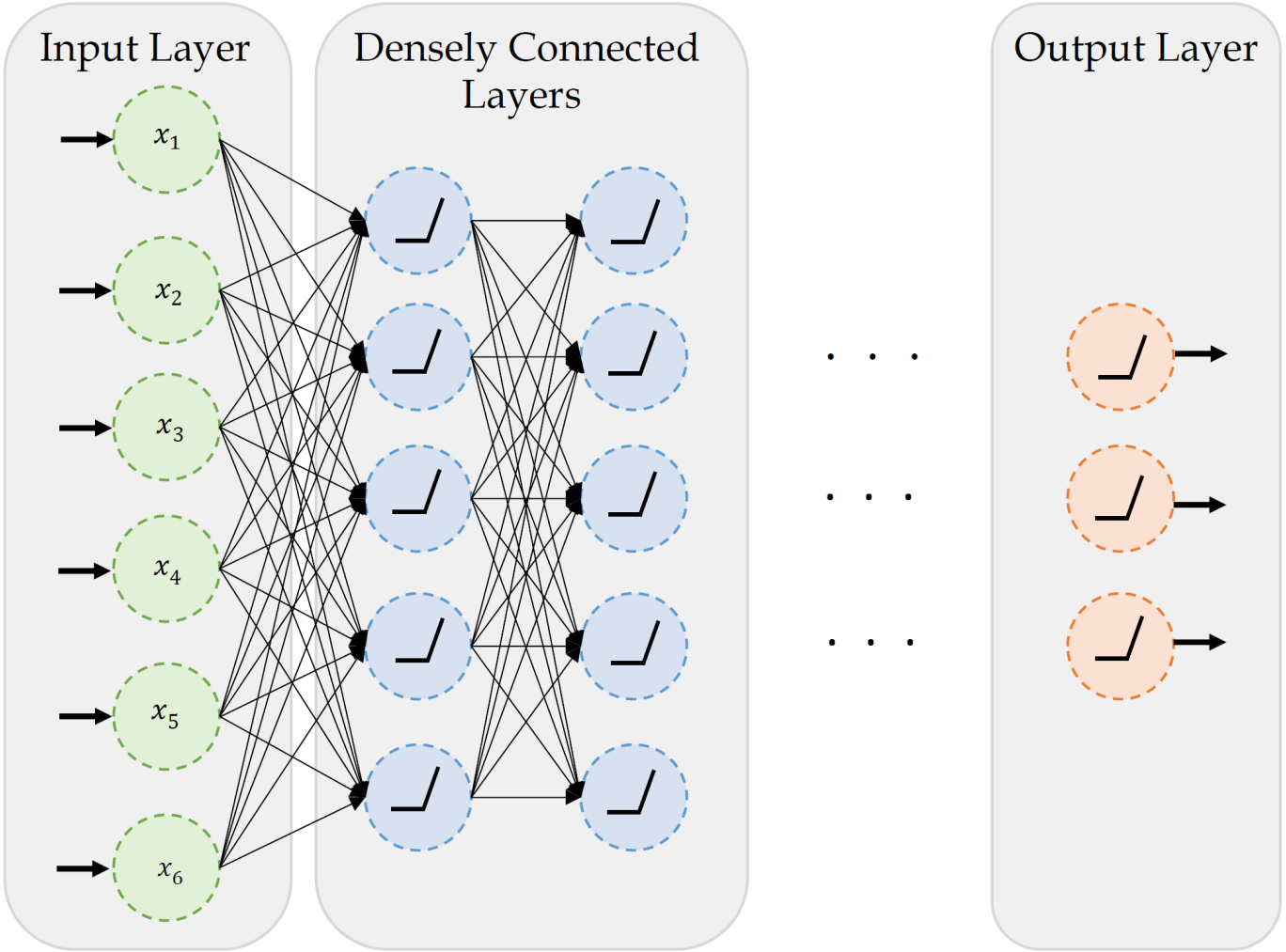
$$
a = \begin{cases} z & \text{if } z > 0 \\ 0 & \text{if } z \leq 0 \end{cases}
$$

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

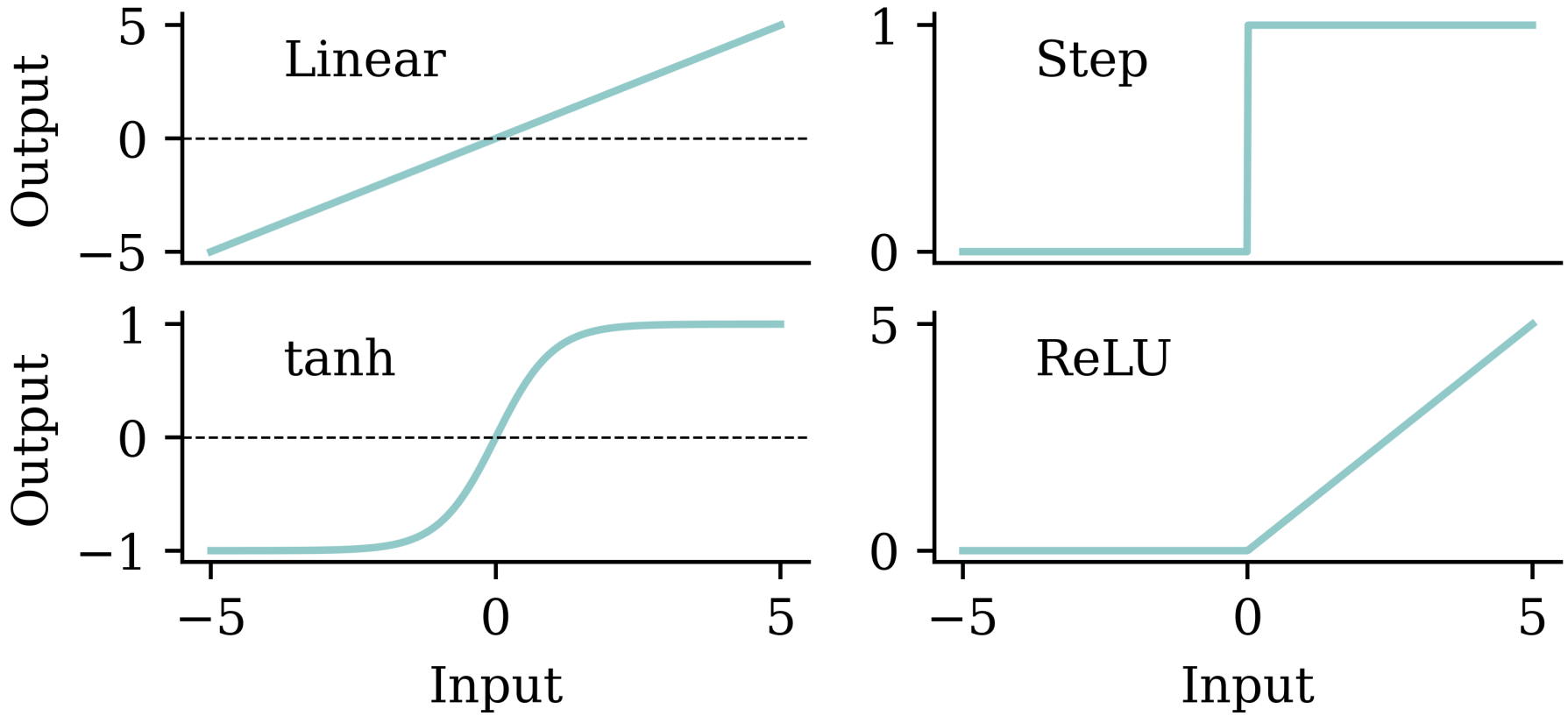
Brains and computers are binary, so make a perceptron with binary data. Seemed reasonable, impossible to train.

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

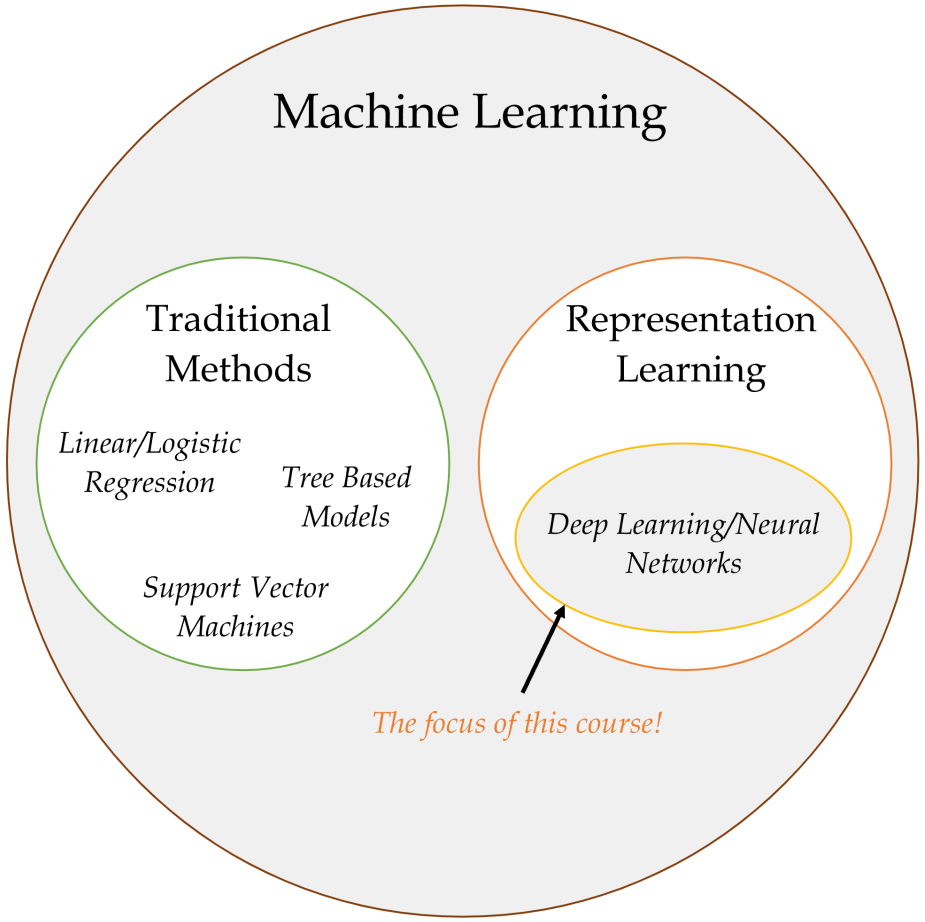


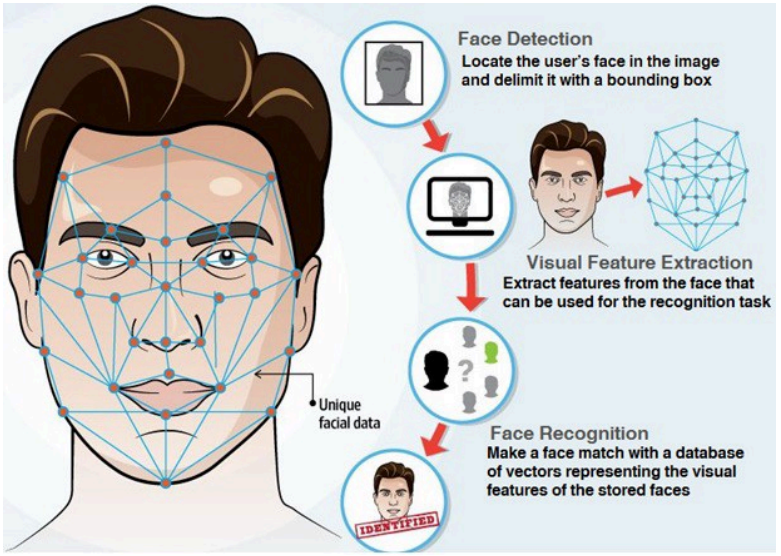
Flexible

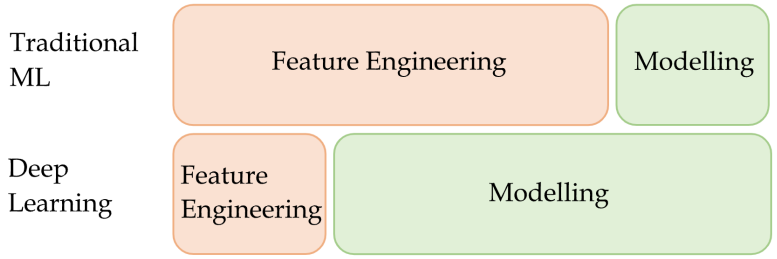
> One can show that an MLP is a **universal approximator**, meaning it can model any suitably smooth function, given enough hidden units, to any desired level of accuracy (Hornik 1991). One can either make the model be “wide” or “deep”; the latter has some advantages…

Source: Murphy (2012), Machine Learning: A Probabilistic Perspective, 1st Ed, p. 566.

Feature engineering







Doesn't mean deep learning is always the best option!

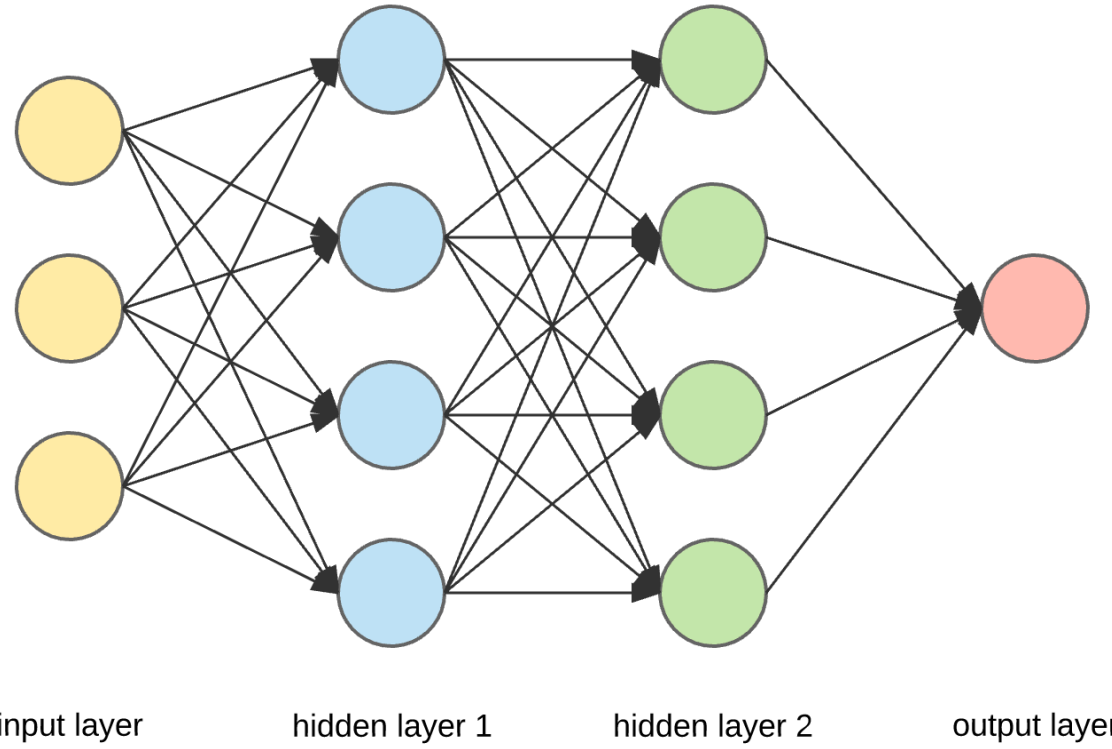
Sources: Marcus Lautier (2022) & Fenjiro (2019), *Face Id: Deep Learning for Face Recognition*, Medium.

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

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

```
Python implementation: CPython
Python version       : 3.11.11
IPython version      : 8.32.0

keras     : 3.8.0
matplotlib: 3.10.0
numpy     : 1.26.4
pandas    : 2.2.3
seaborn   : 0.13.2
scipy     : 1.13.1
torch     : 2.5.1+cu124
tensorflow: 2.18.0
tf_keras  : 2.18.0
```

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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
- minimax algorithm
- neural network architecture
- perceptron
- ReLU
- representation learning
- sigmoid activation function
- targets
- weights (in a neuron)