HeiCAD
Heine Center for Artificial Intelligence and Data Science

HeiCADLearn

Practical Introduction to AI and Data Science for Doctoral Researchers in Medicine and Biology

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Accompanying GitHub repository for this course:
https://github.com/JoanaGrah/HeiCADLearn/Intro_MedBio_July2021

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Day 2

1 Recap

2 A short introduction to data science in Python

3 From linear regression to neural networks

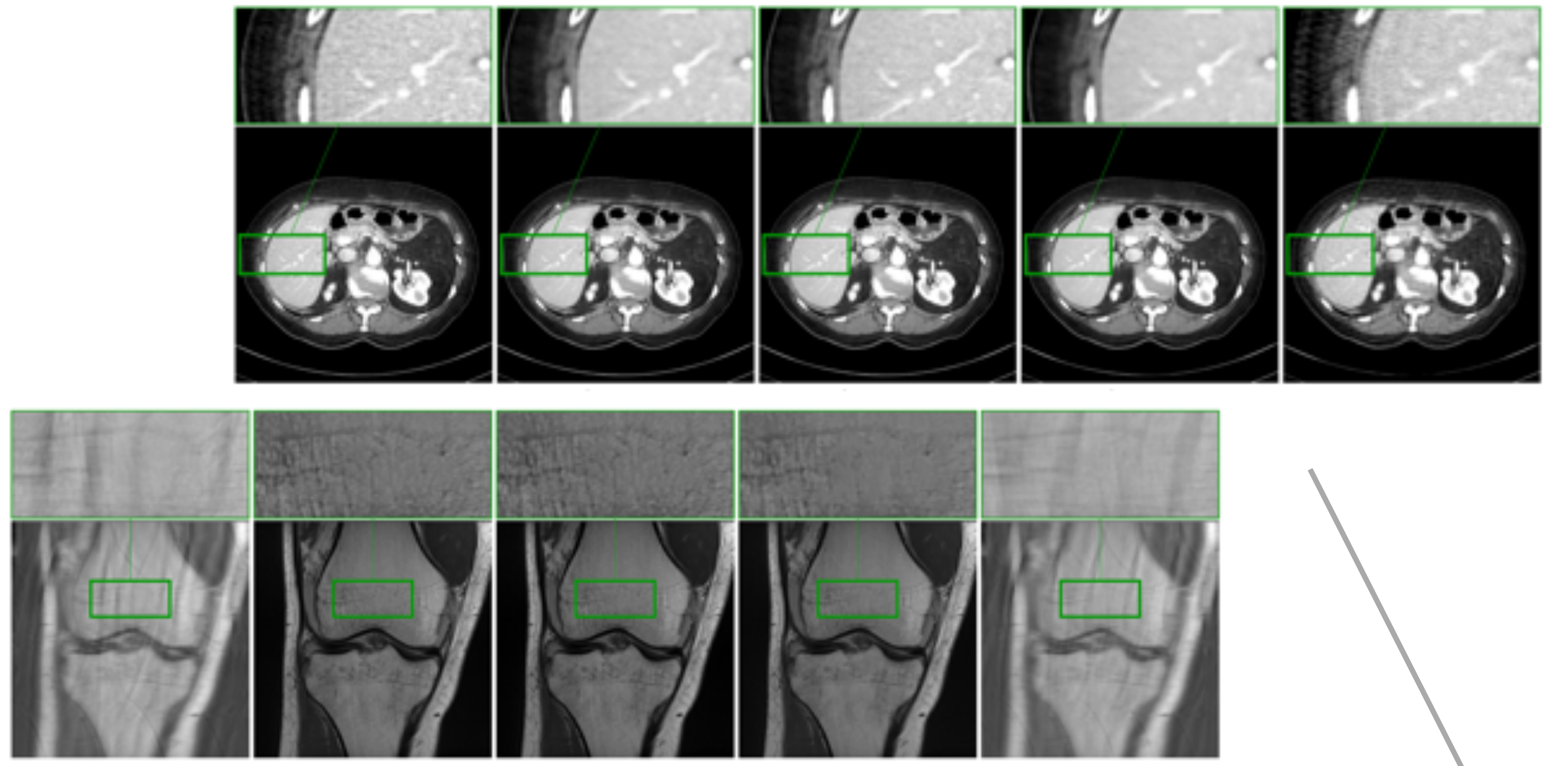
BREAK

4 AI in practice:
Deep learning for biology and medicine
'Homework': Examples from your research area
(data and AI methods)

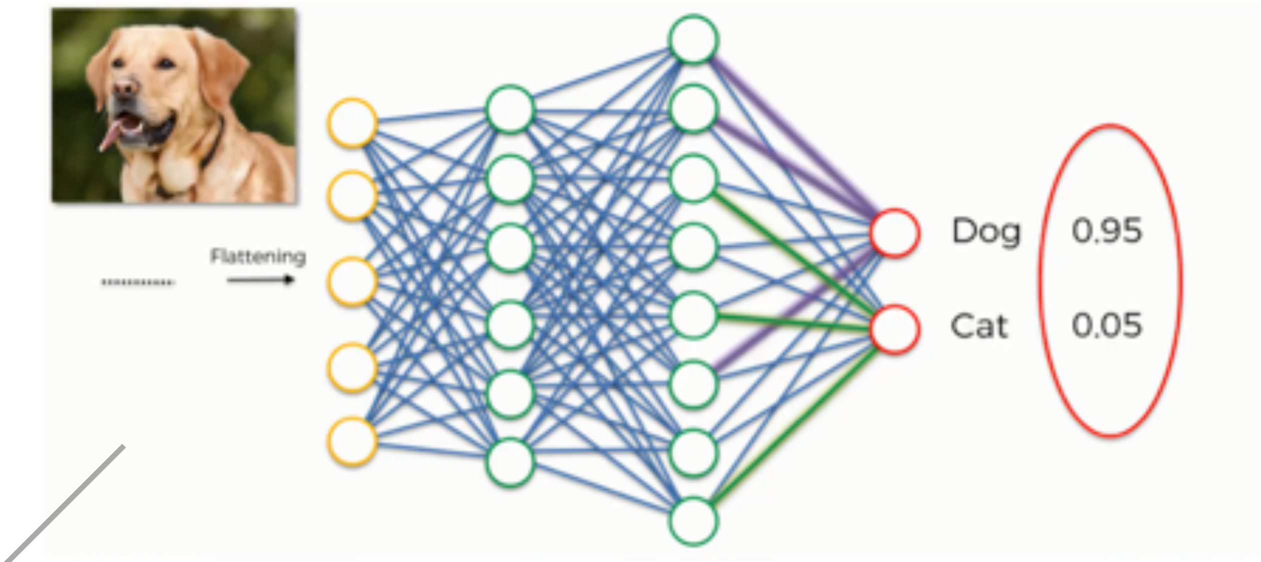
5 Revision: What is AI?

Day 3

Deep learning example

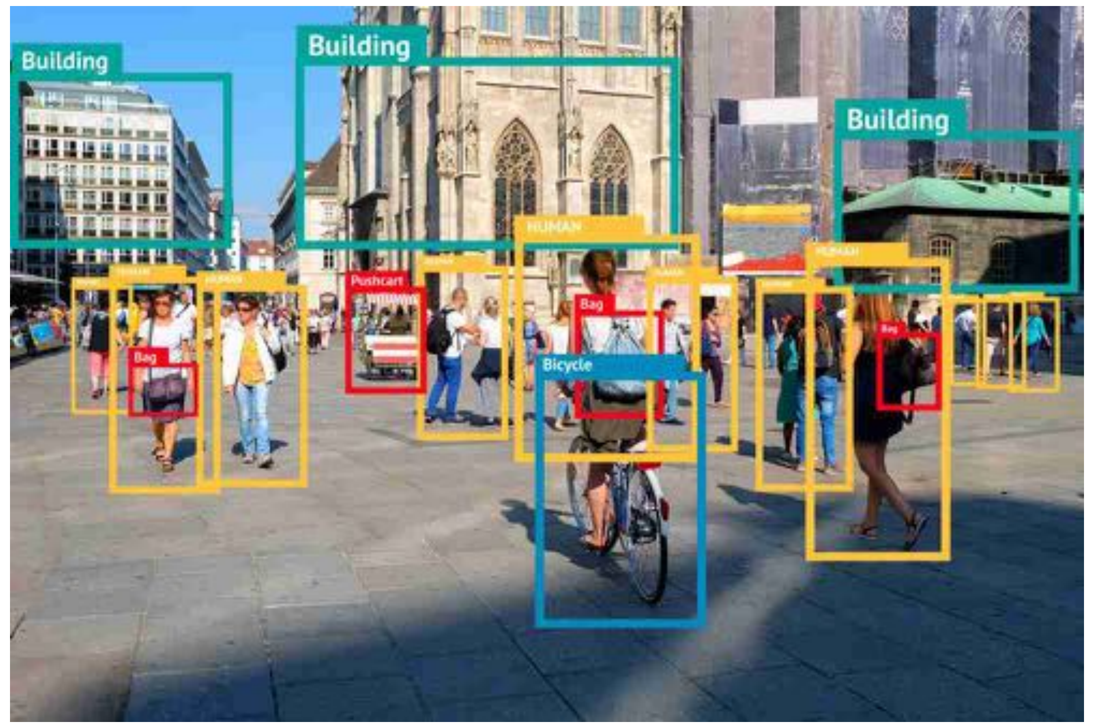


Medical image reconstruction

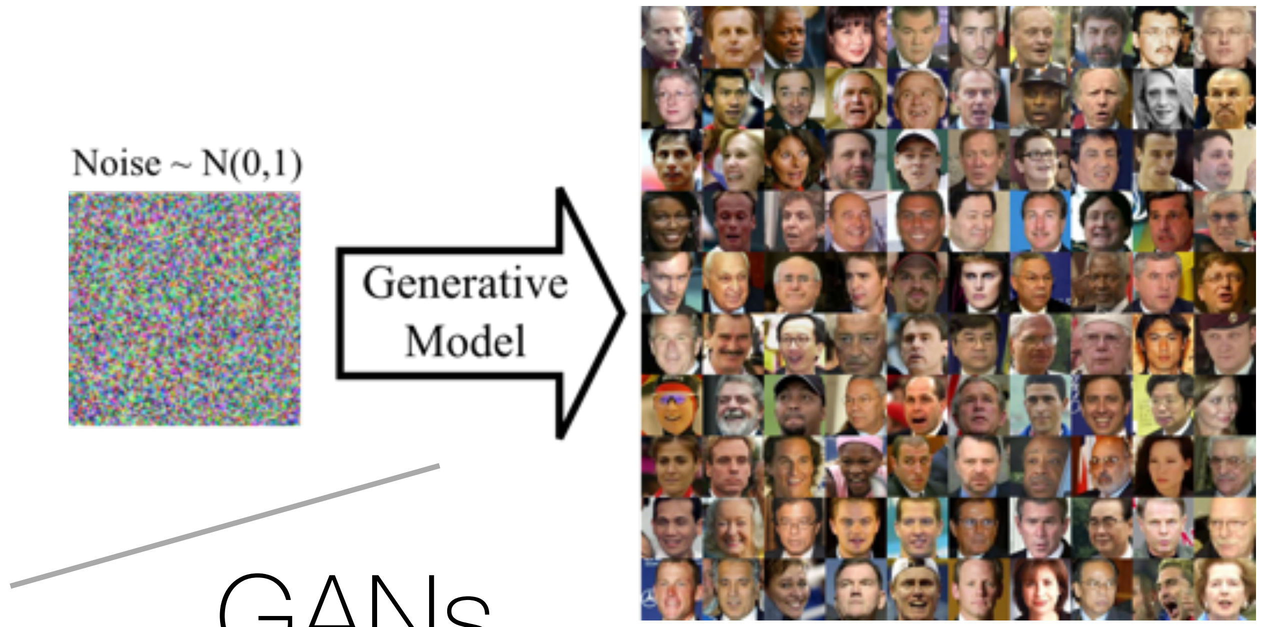


Classification

Artificial Neural Networks



Object recognition



GANs

Semantic segmentation

Recap

miro

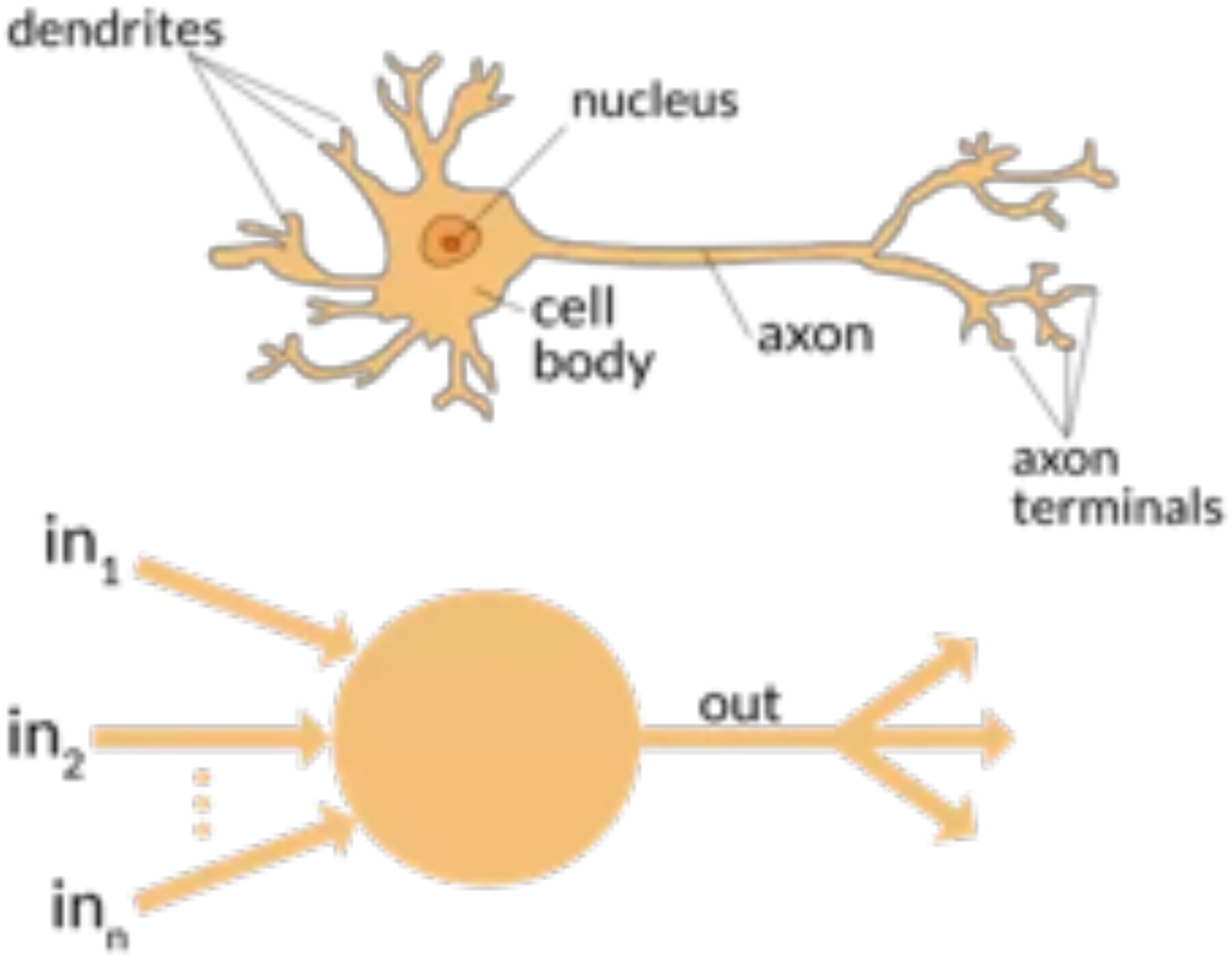
Jupyter Notebook Session

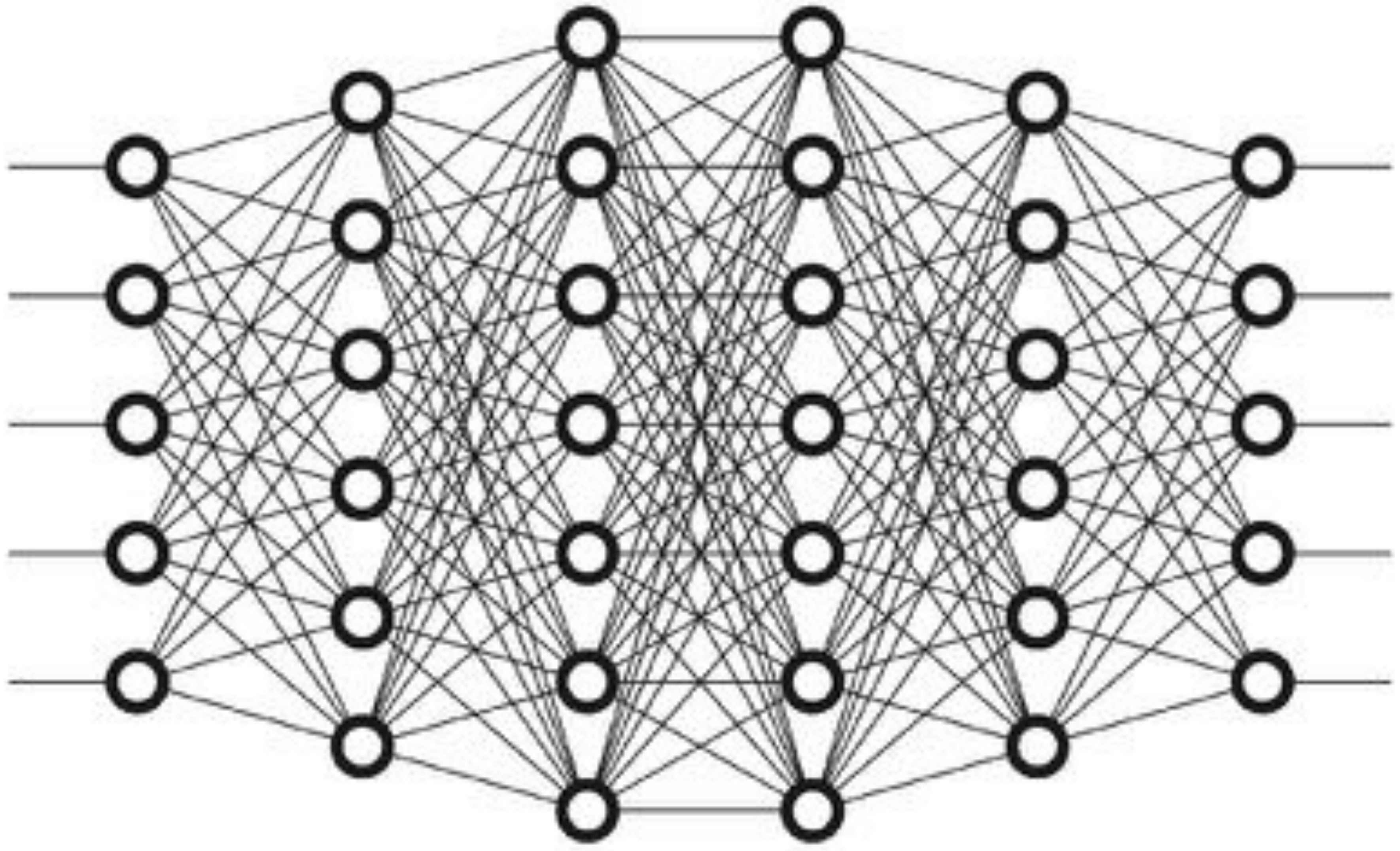
https://wiki.hhu.de/display/HPC/Wissenschaftliches+Hochleistungs-Rechnen+am+ZIM

https://wiki.hhu.de/display/HPC/Jupyter

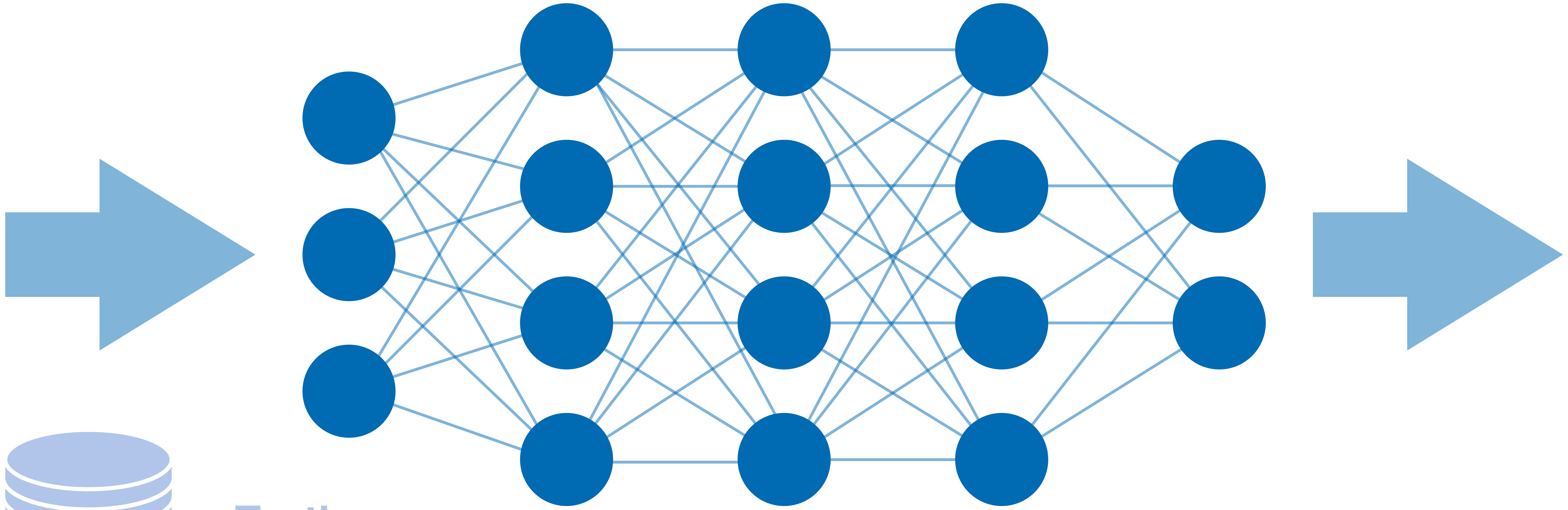
https://jupyter.hpc.rz.uni-duesseldorf.de/hub/

Artificial Neural Networks

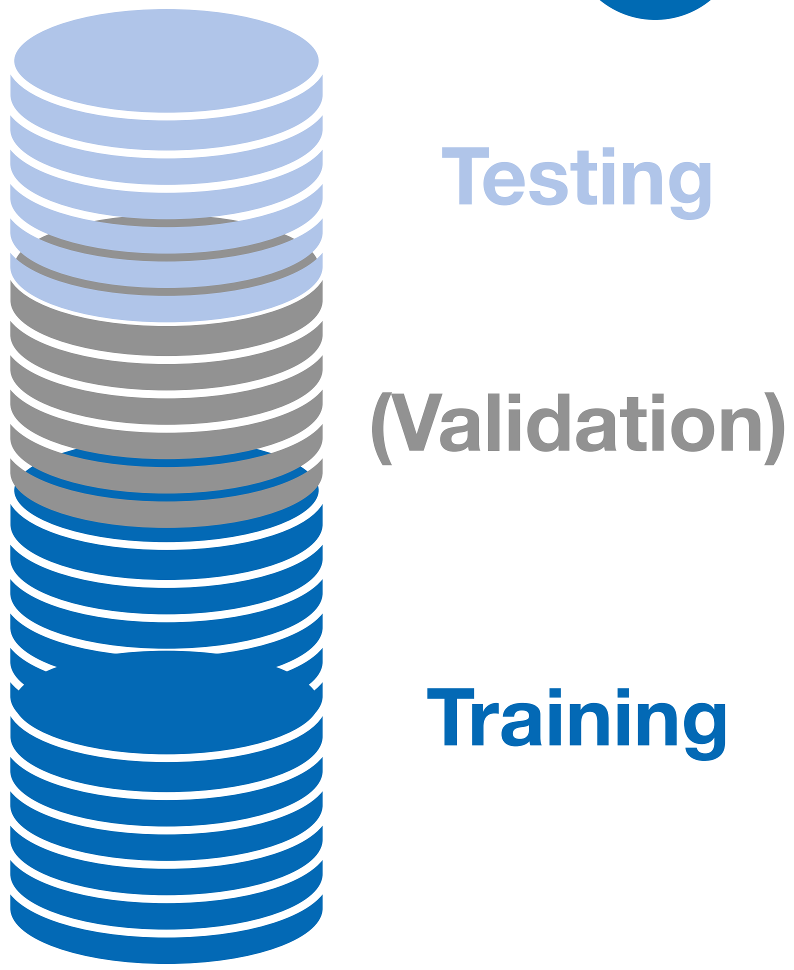




Deep Learning / Neural Networks

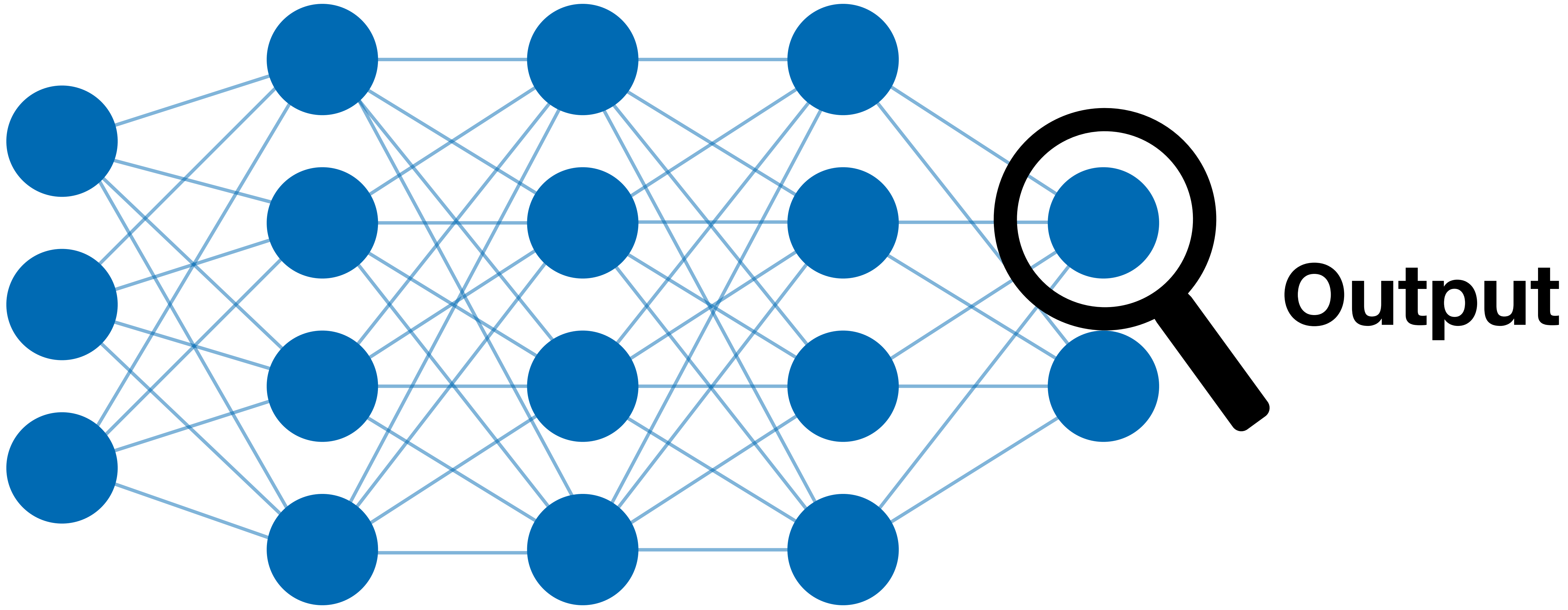


Harold C. Burger, Christian J. Schuler, and Stefan Harmeling. "Image denoising: Can plain neural networks compete with BM3D?."
2012 IEEE conference on computer vision and pattern recognition. IEEE, 2012.



Mathematical explanation: Higham, Catherine F., and Desmond J. Higham. "Deep learning: An introduction for applied mathematicians." SIAM Review 61.4 (2019): 860-891.

Deep Learning / Neural Networks



<u>Loss function / cost function</u>

$$\sum_{\text{\#samples}} \text{distance}\left(\substack{\text{target}\\ \text{outputs}} \left(\text{inputs} \right), \substack{\text{network}\\ \text{outputs}} \left(\text{inputs} \right) \right)$$

Deep Learning / Neural Networks

Photo by Victor Freitas on Unsplash

Training

aka: parameter optimisation

How to optimise a function?

Deep Learning / Neural Networks

How to optimise a function? → Gradient descent

Photo by **Gianluca Grisenti** from **Pexels**

https://upload.wikimedia.org/wikipedia/commons/4/4c/Gradient_Descent_in_2D.webm

Deep Learning / Neural Networks

How to optimise a function? → Gradient descent

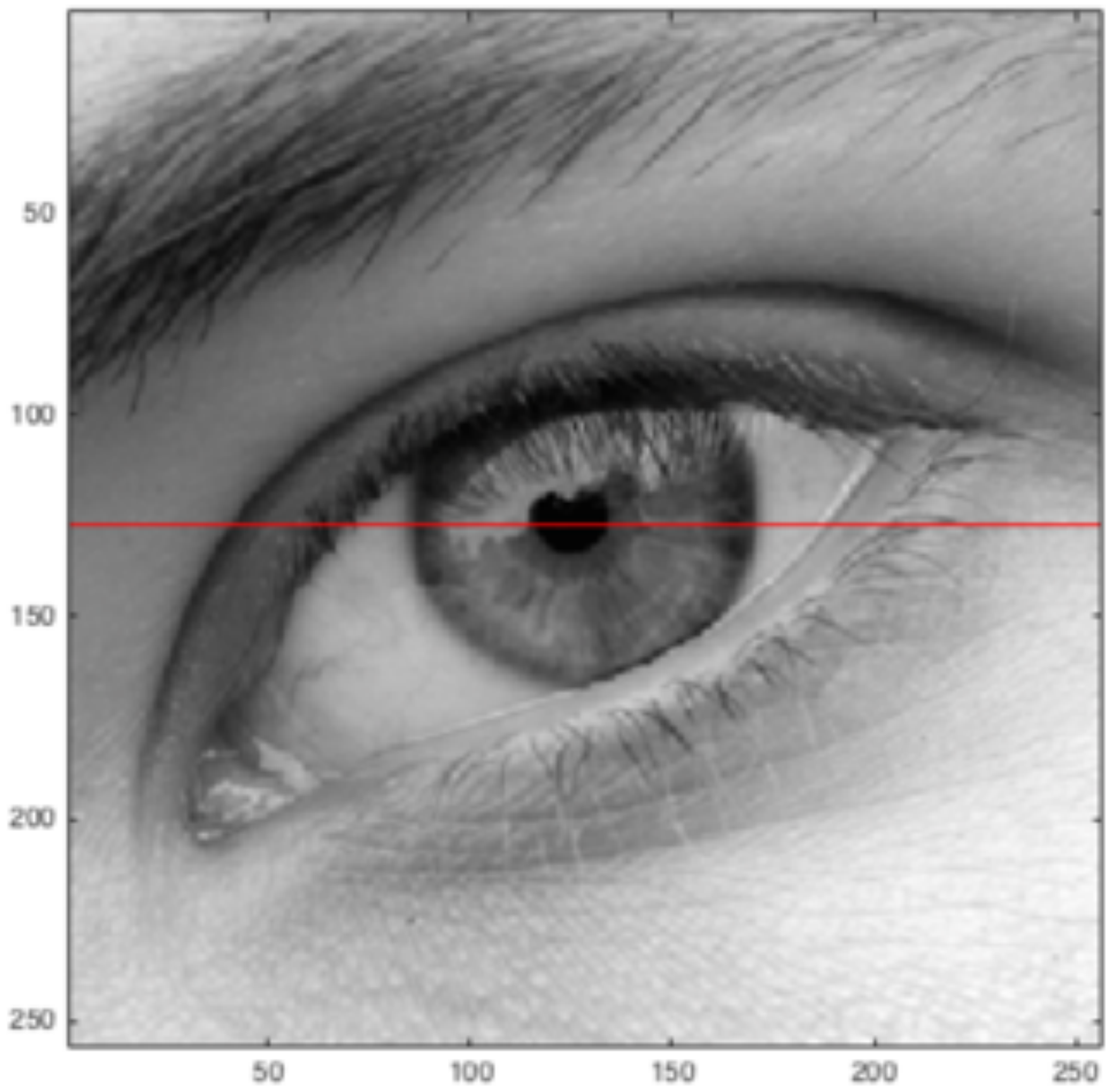
The size of your hiking steps is called the <u>learning rate</u>

Photo by **Gianluca Grisenti** from **Pexels**

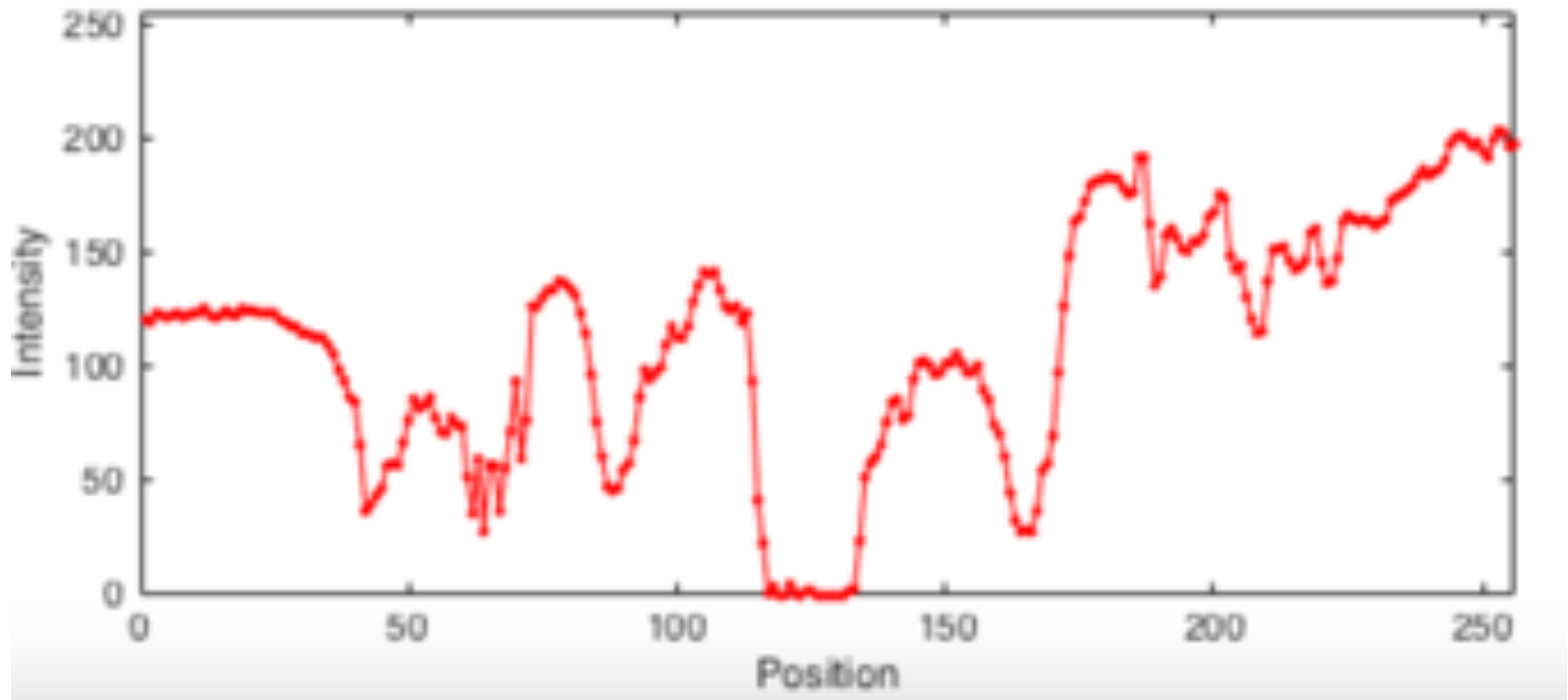
https://upload.wikimedia.org/wikipedia/commons/4/4c/Gradient_Descent_in_2D.webm

The method (in simple terms the chain rule) is called <u>backpropagation</u>

How does a computer see a picture?

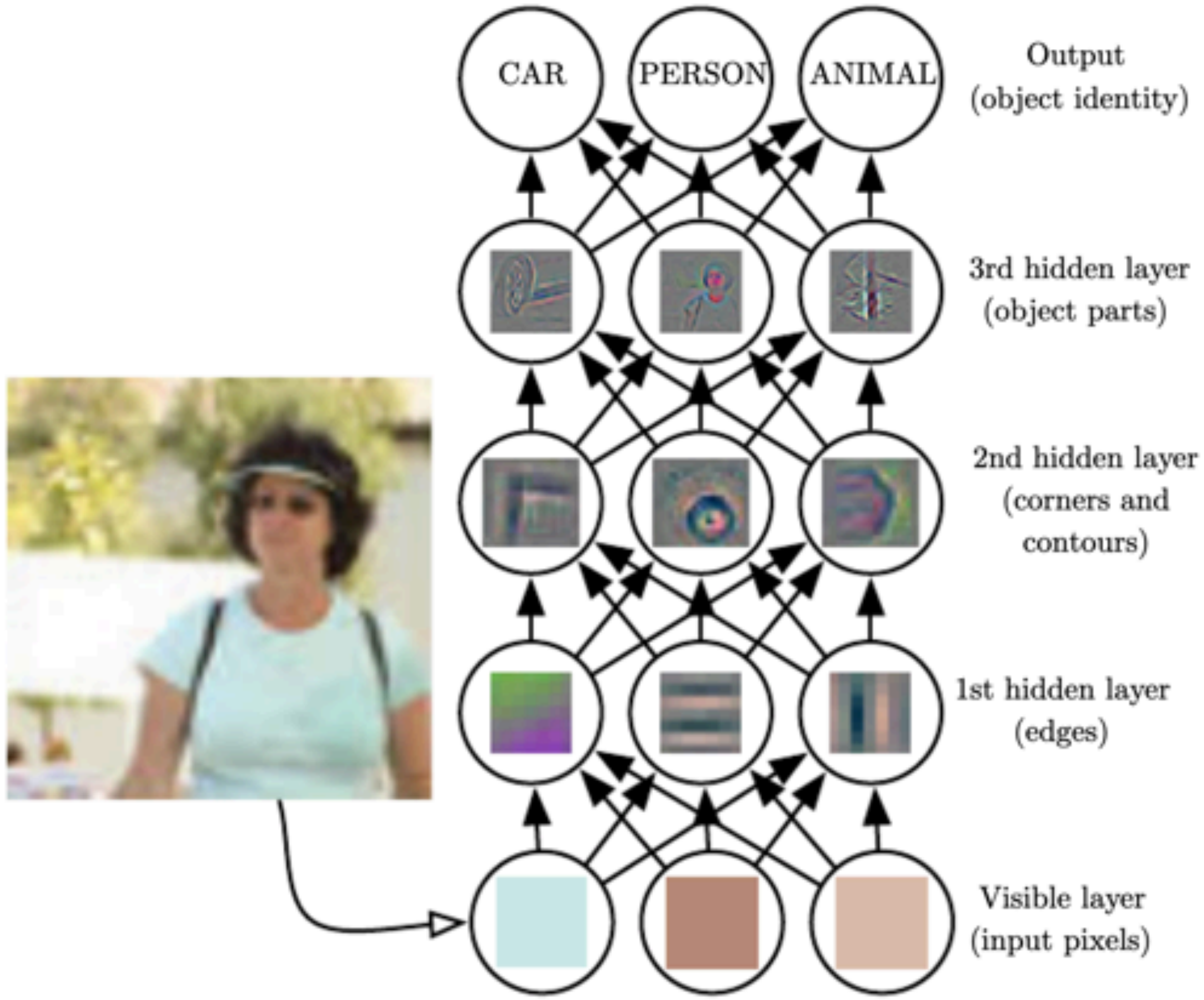


50
100
150
200
250
50
100
150
200
250



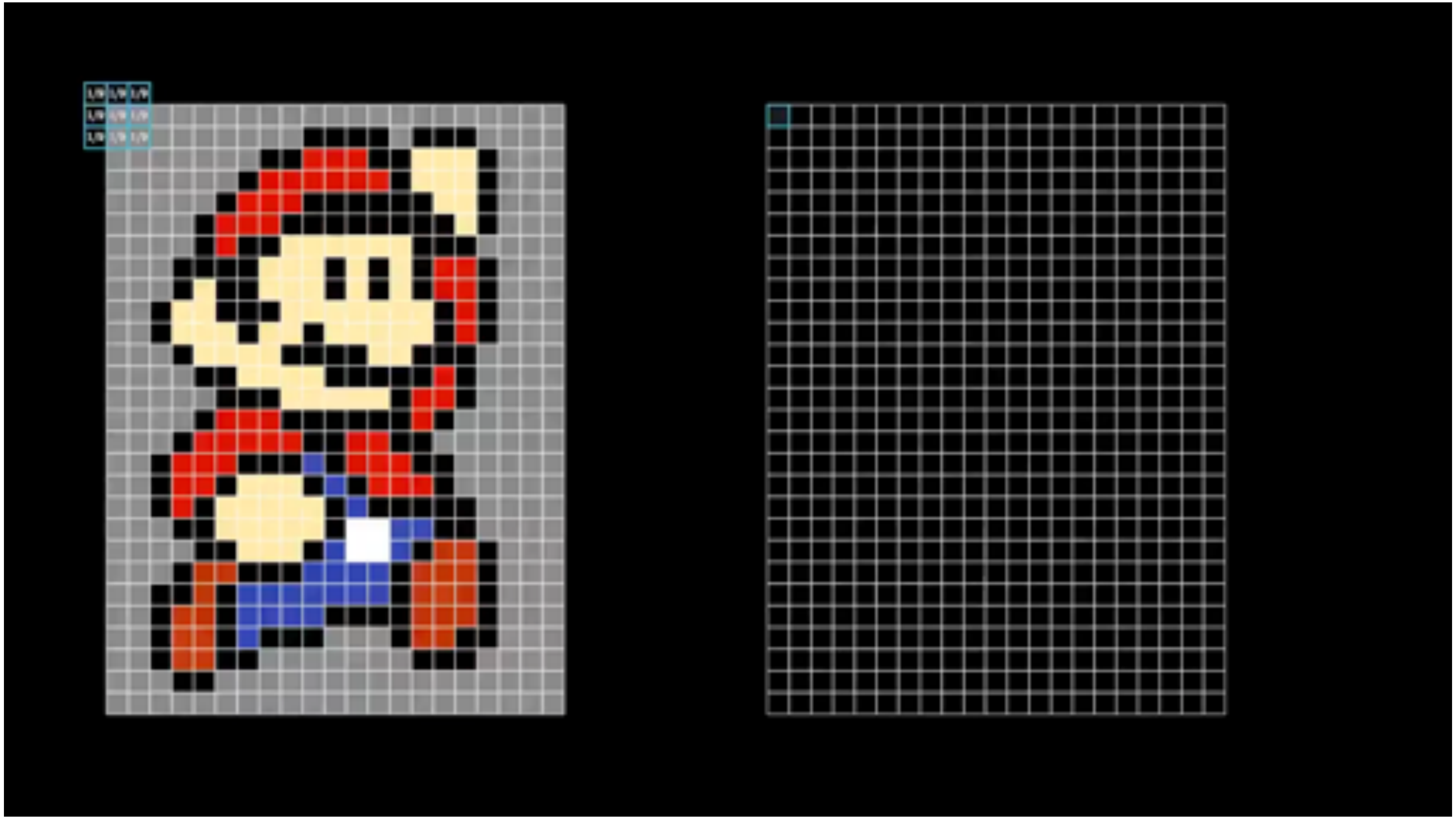
250
200
150
100
50
0
Intensity
0
50
100
150
200
250
Position

Convolutional Neural Networks



https://www.deeplearningbook.org

Convolutional Neural Networks



https://twitter.com/3blue1brown/status/1303489896519139328?s=20

Convolutional Neural Networks

Feature Visualization

How neural networks build up their understanding of images

Edges (layer conv2d0) **Textures** (layer mixed3a) **Patterns** (layer mixed4a) **Parts** (layers mixed4b & mixed4c) **Objects** (layers mixed4d & mixed4e)

Feature visualization allows us to see how GoogLeNet [1], trained on the ImageNet [2] dataset, builds up its understanding of images over many layers. Visualizations of all channels are available in the appendix.

https://distill.pub/2017/feature-visualization/

Jupyter Notebook Session

https://wiki.hhu.de/display/HPC/Wissenschaftliches+Hochleistungs-Rechnen+am+ZIM

https://wiki.hhu.de/display/HPC/Jupyter

https://jupyter.hpc.rz.uni-duesseldorf.de/hub/

BREAK

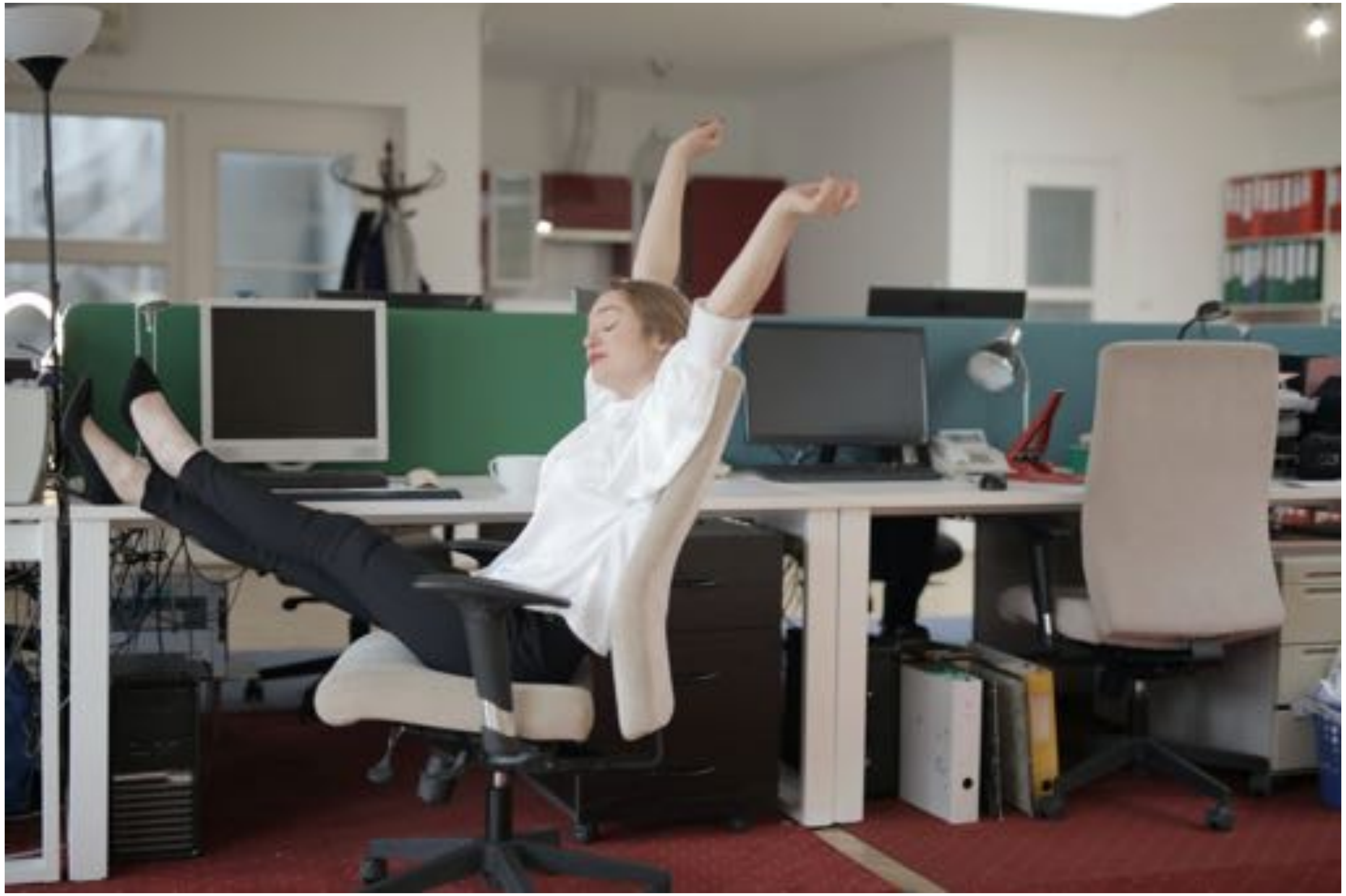
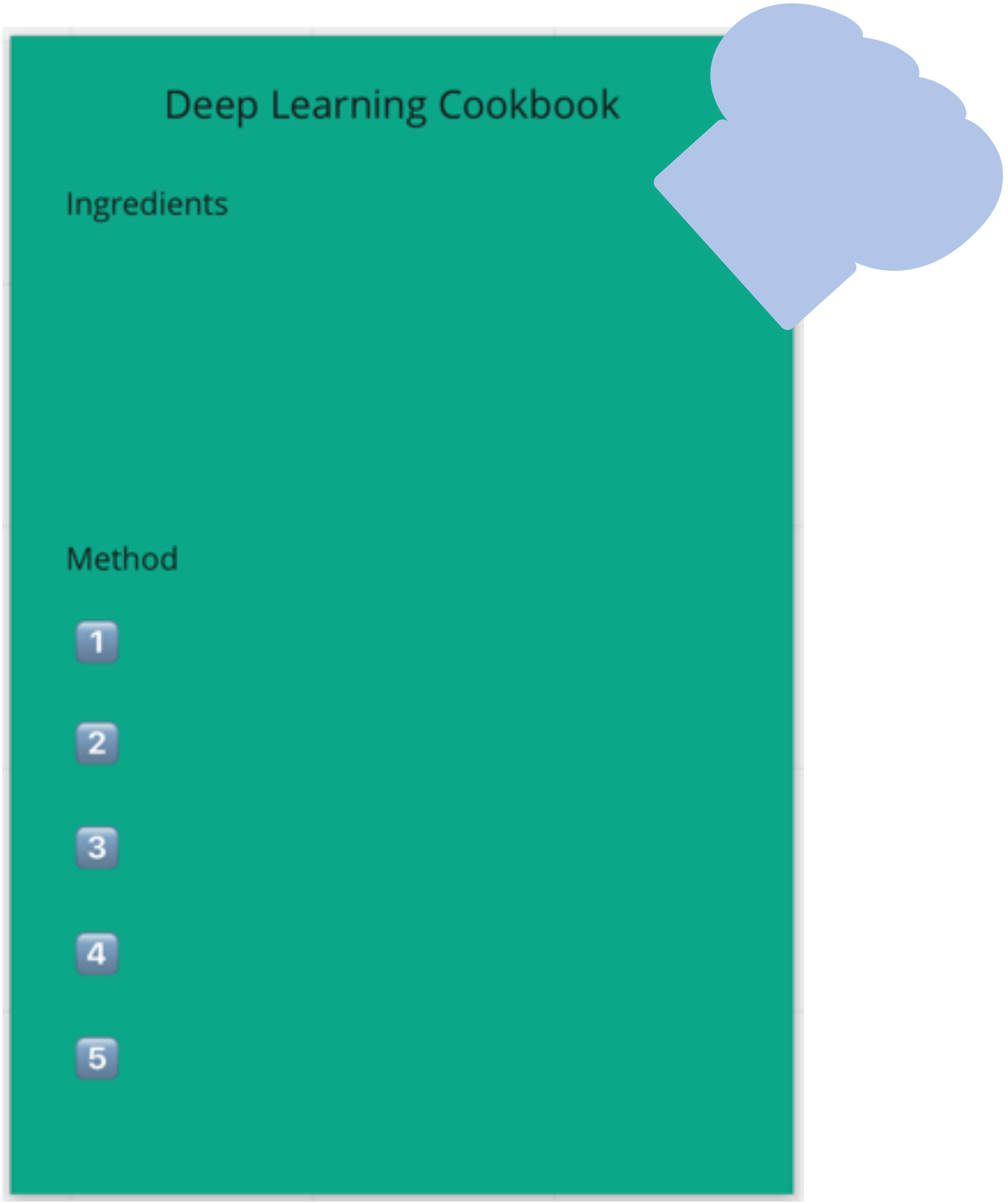


Photo by **Andrea Piacquadio** from **Pexels**

Convolutional Neural Networks



Group Work

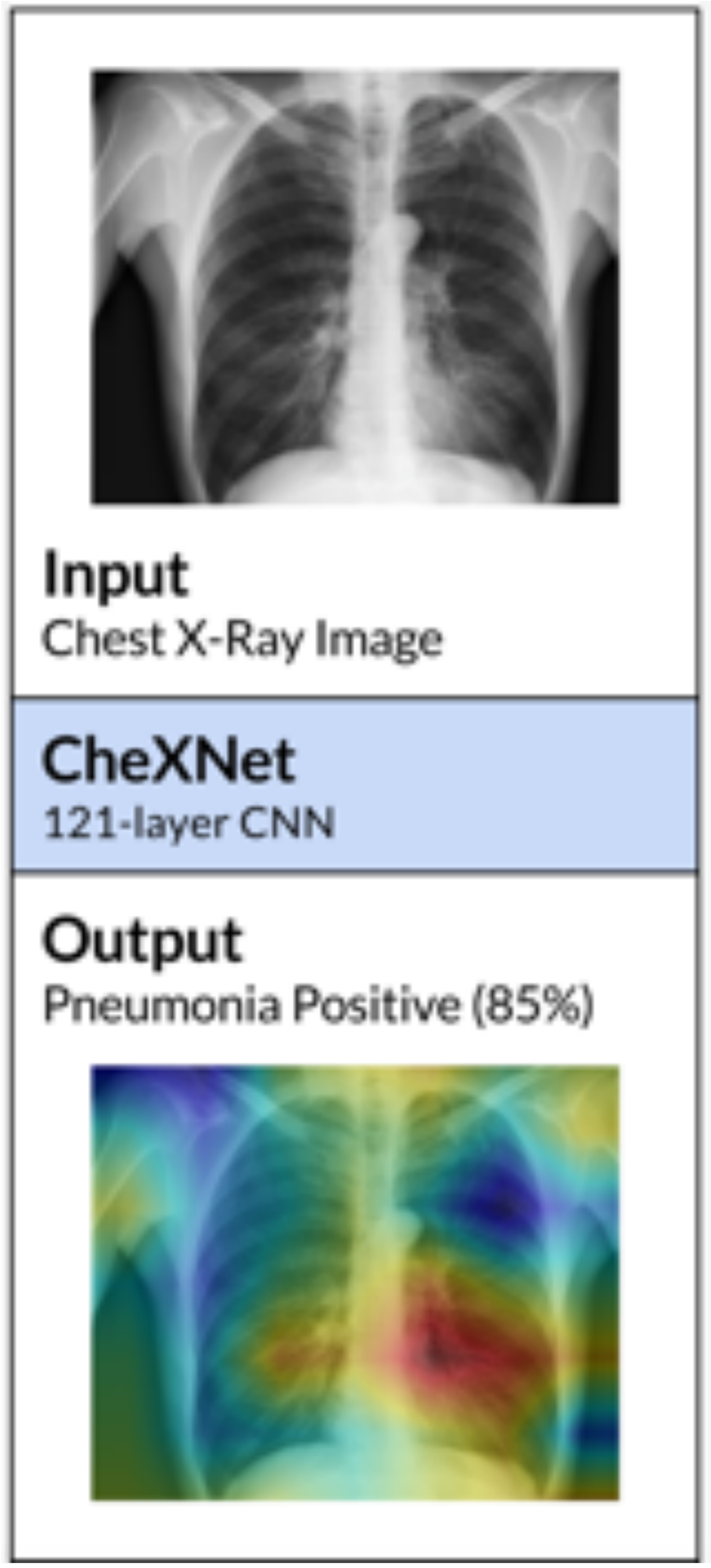
Think of one example where AI or more particularly machine learning is applied in your research area that you find particularly interesting and useful for your doctoral research.

What type of data is needed in this case?

What kind of AI models are used?

Medical example: CheXNet

Rajpurkar, Pranav, et al. "Chexnet: Radiologist-level pneumonia detection on chest x-rays with deep learning." arXiv preprint arXiv:1711.05225 (2017).



Our model, CheXNet, is a 121-layer convolutional neural network that inputs a chest X-ray image and outputs the probability of pneumonia along with a heatmap localizing the areas of the image most indicative of pneumonia.

We train CheXNet on the recently released ChestX-ray14 dataset, which contains 112,120 frontal-view chest X-ray images individually labeled with up to 14 different thoracic diseases, including pneumonia. We use dense connections and batch normalization to make the optimization of such a deep network tractable.

Medical example: CheXNet

Rajpurkar, Pranav, et al. "Chexnet: Radiologist-level pneumonia detection on chest x-rays with deep learning." arXiv preprint arXiv:1711.05225 (2017).

We train on ChestX-ray14, the largest publicly available chest X- ray dataset.

The dataset, released by the NIH, contains 112,120 frontal-view X-ray images of 30,805 unique patients, annotated with up to 14 different thoracic pathology labels using NLP methods on radiology reports. We label images that have pneumonia as one of the annotated pathologies as positive examples and label all other images as negative examples for the pneumonia detection task.

We collected a test set of 420 frontal chest X-rays. Annotations were obtained independently from four practicing radiologists at Stanford University, who were asked to label all 14 pathologies. We then evaluate the performance of an individual radiologist by using the majority vote of the other 3 radiologists as ground truth. Similarly, we evaluate CheXNet using the majority vote of 3 of 4 radiologists, repeated four times to cover all groups of 3.

Medical example: CheXNet

Rajpurkar, Pranav, et al. "Chexnet: Radiologist-level pneumonia detection on chest x-rays with deep learning." arXiv preprint arXiv:1711.05225 (2017).

	F1 Score (95% CI)
Radiologist 1	0.383 (0.309, 0.453)
Radiologist 2	0.356 (0.282, 0.428)
Radiologist 3	0.365 (0.291, 0.435)
Radiologist 4	0.442 (0.390, 0.492)
Radiologist Avg.	0.387 (0.330, 0.442)
CheXNet	0.435 (0.387, 0.481)

We find that the model exceeds the average radiologist performance on the pneumonia detection task.

We compute the F1 score for each individual radiologist and for CheXNet against each of the other 4 labels as ground truth. We report the mean of the 4 resulting F1 scores for each radiologist and for CheXNet, along with the average F1 across the radiologists. We compare radiologists and our model on the F1 metric, which is the harmonic average of the precision and recall. CheXNet achieves an F1 score of 0.435 (95% CI 0.387, 0.481), higher than the radiologist average of 0.387 (95% CI 0.330, 0.442). We use the bootstrap to find that the difference in performance is statistically significant.

Homework

Go through the Fashion MNIST example

https://www.tensorflow.org/tutorials/keras/classification

No worries, we'll be running the code together and go through it in more detail in the third session!

Fill in the table in the miroboard (your research, data, ai tools and resources)