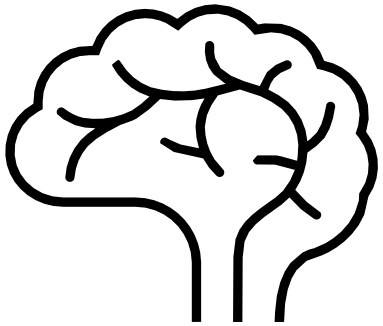
Introduction to Machine Learning

Artificial Neural Networks (ANNs)

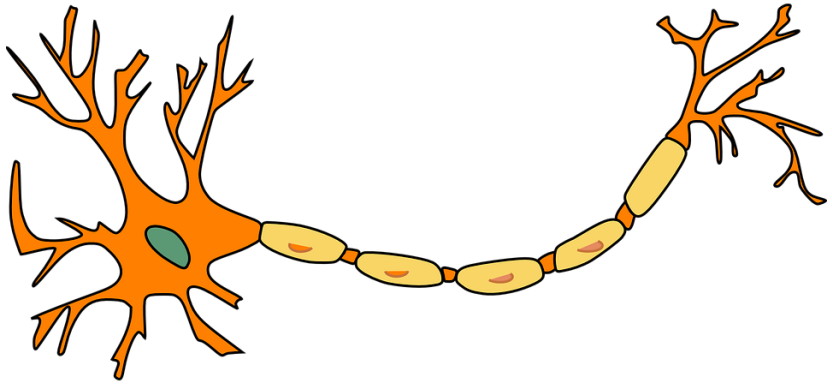
Artifical Neural Networks (ANNs)

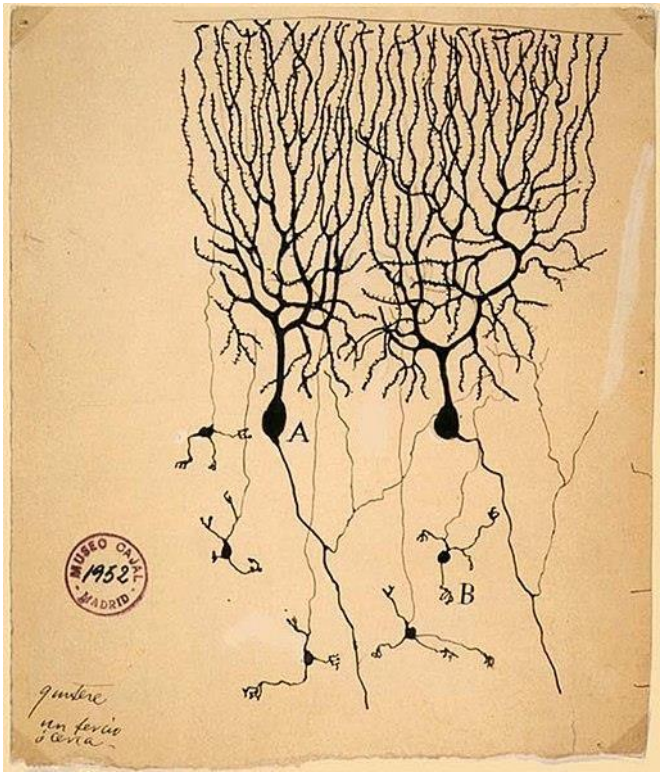


The human brain is capable of solving a wide variety of highly complex tasks seemingly „effortlessly”.

Through neuroscience, we have a fundamental understanding of the structure and functioning of the brain.

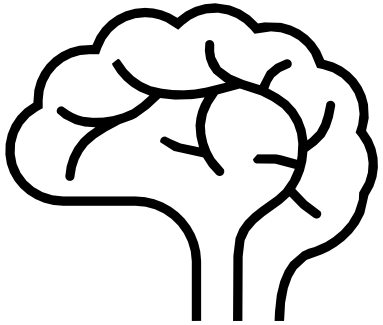
Idea:
We design an algorithm modeled after nature, called an Artificial Neural Network.





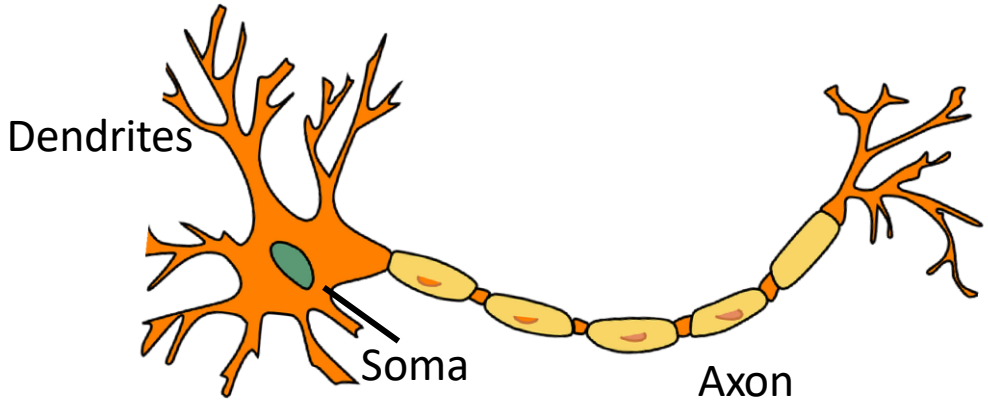
Santiago Ramón y Cajal, 1899

Artifical Neural Networks (ANNs)

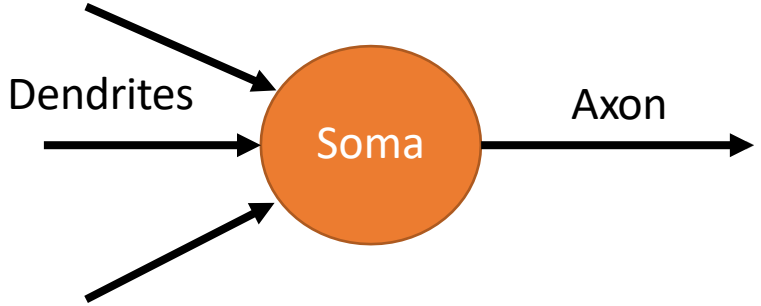


1. We imitate the structure of a biological nerve cell

Biological nerve cell



Node in ANN



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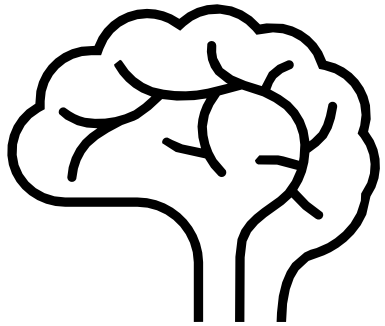
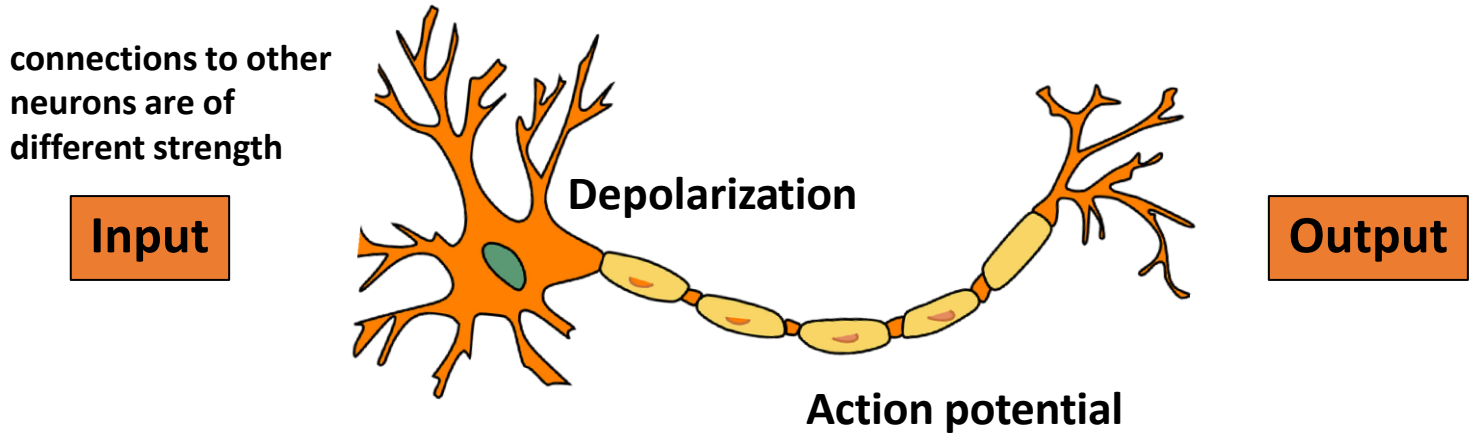


2. We imitate **the stimulus processing** of a biological nerve cell

Biological nerve cell



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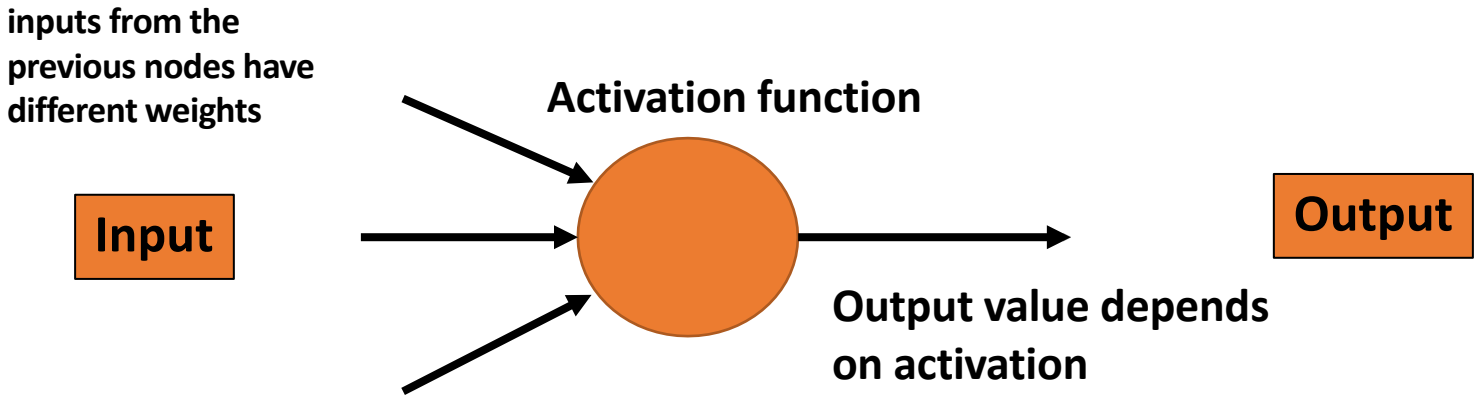

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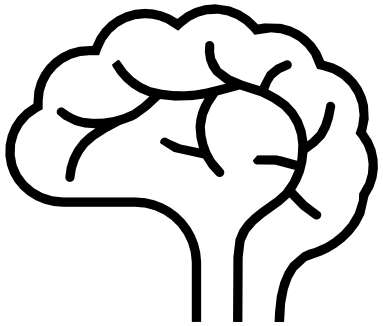

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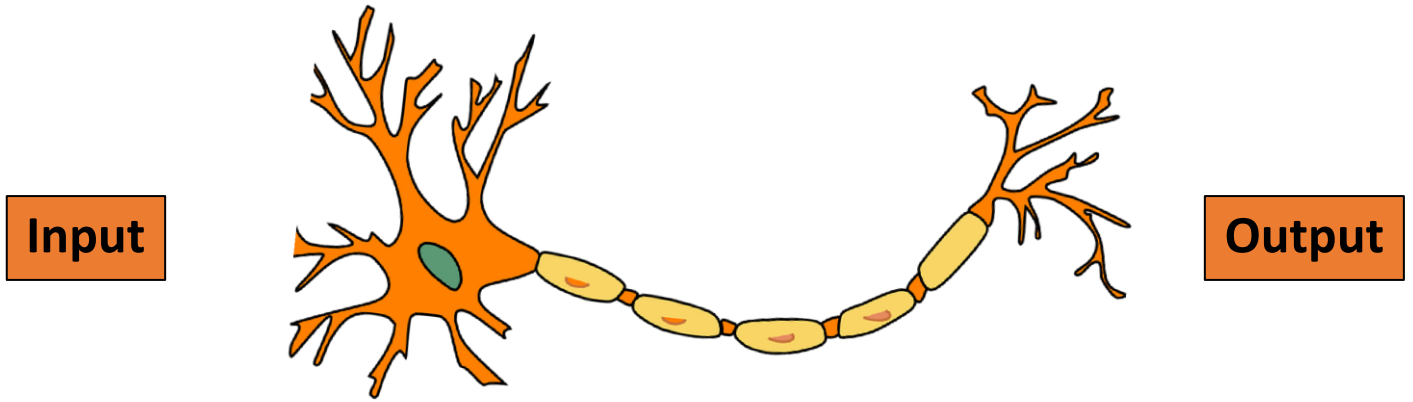

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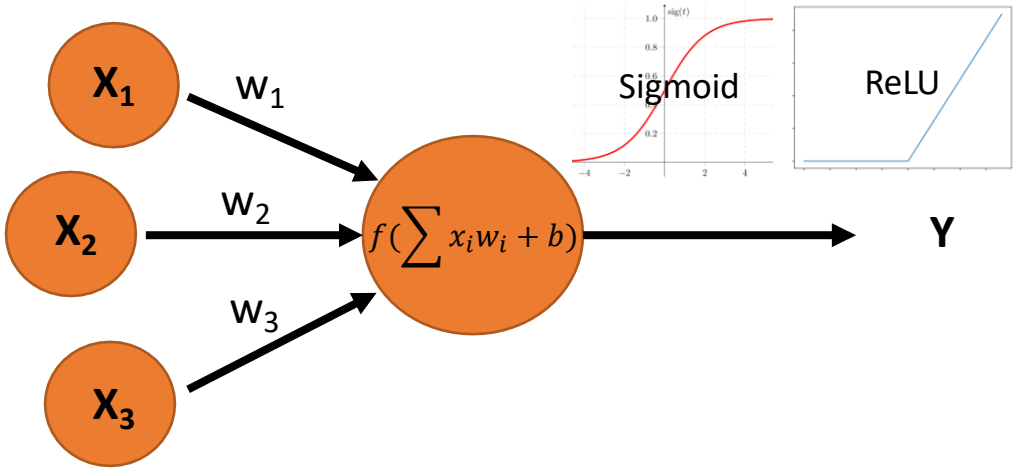
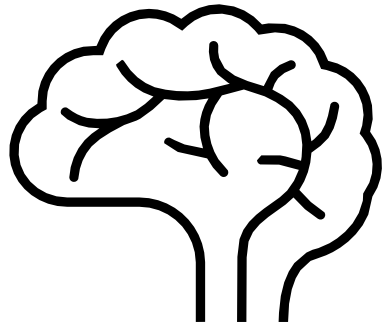


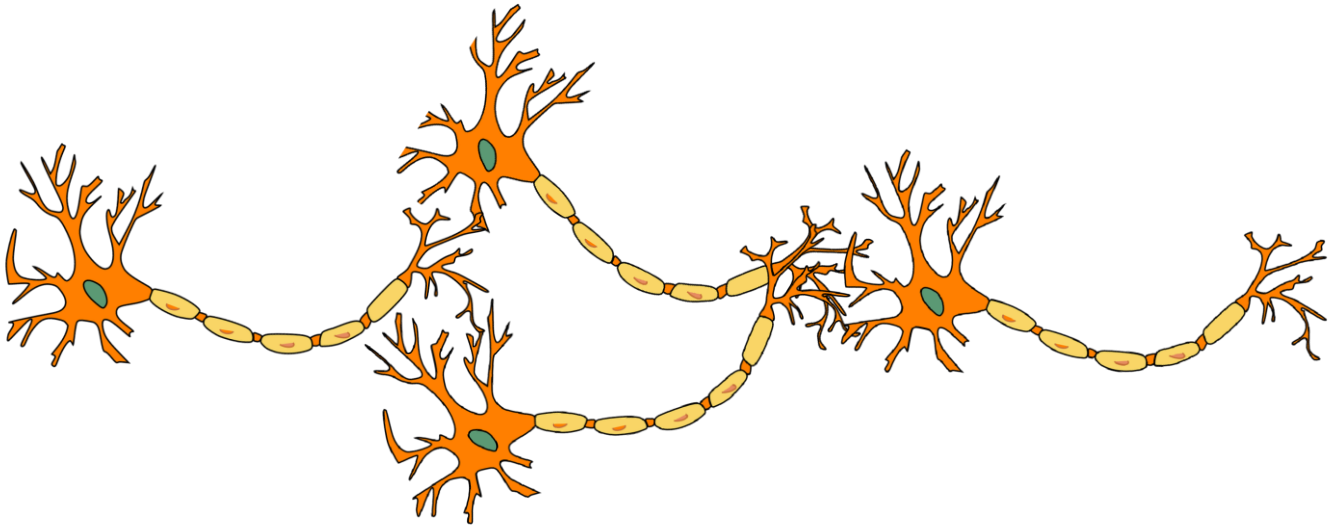
x = Inputs
w = Weights
b = Bias
f() = activation function
Y = Output

Artifical Neural Networks (ANNs)



3. We imitate the structure of a neural network

Biological nerve cell



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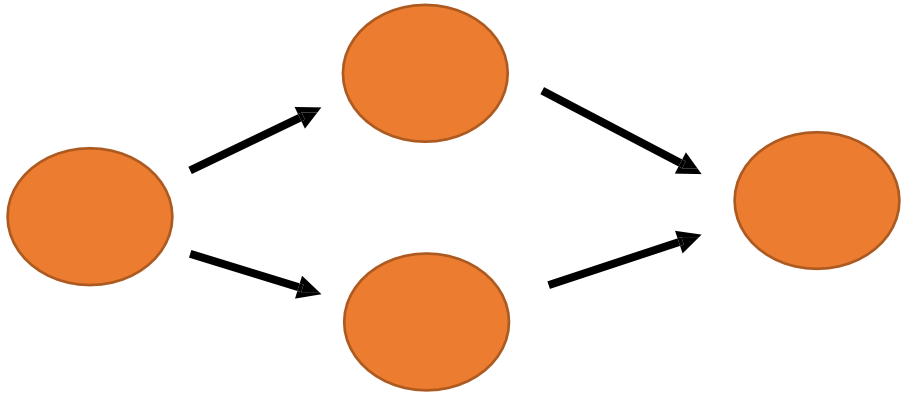

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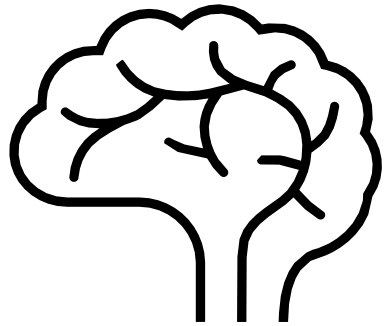
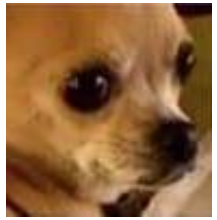
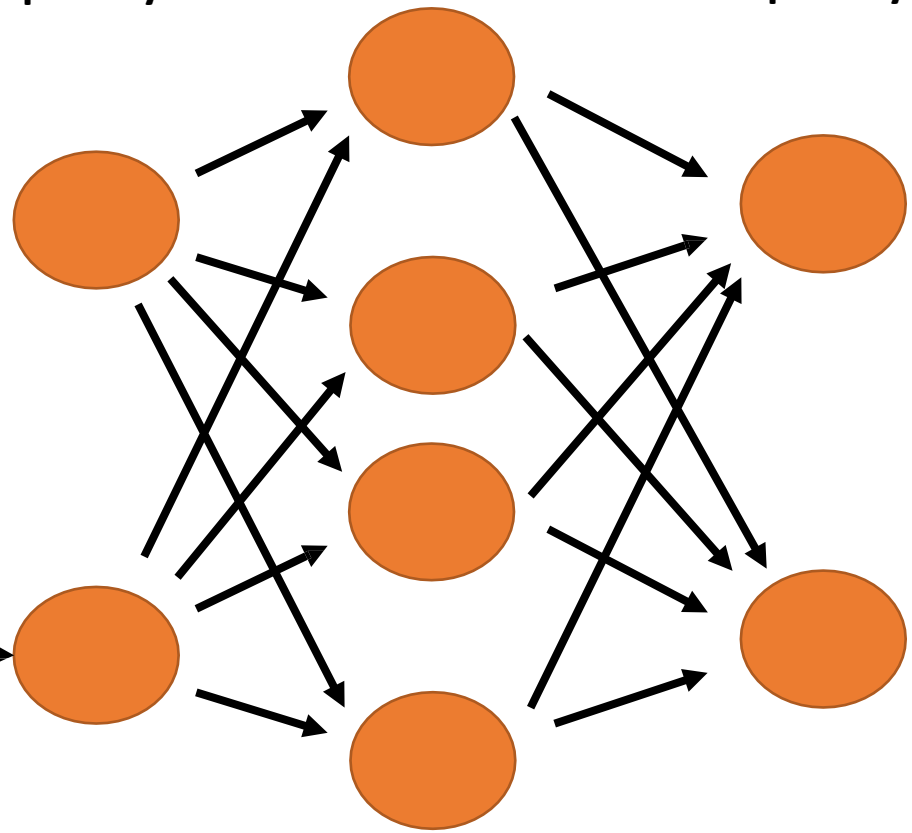


4. We train our ANN with our features and labels

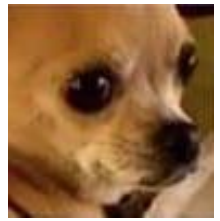


Features

HOG_Pixel_1	HOG_Pixel_2	...	Red_Bin1	Red_Bin2	...
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...



1.34



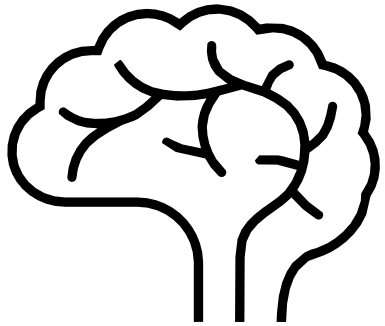
1

ArgMax

0.39

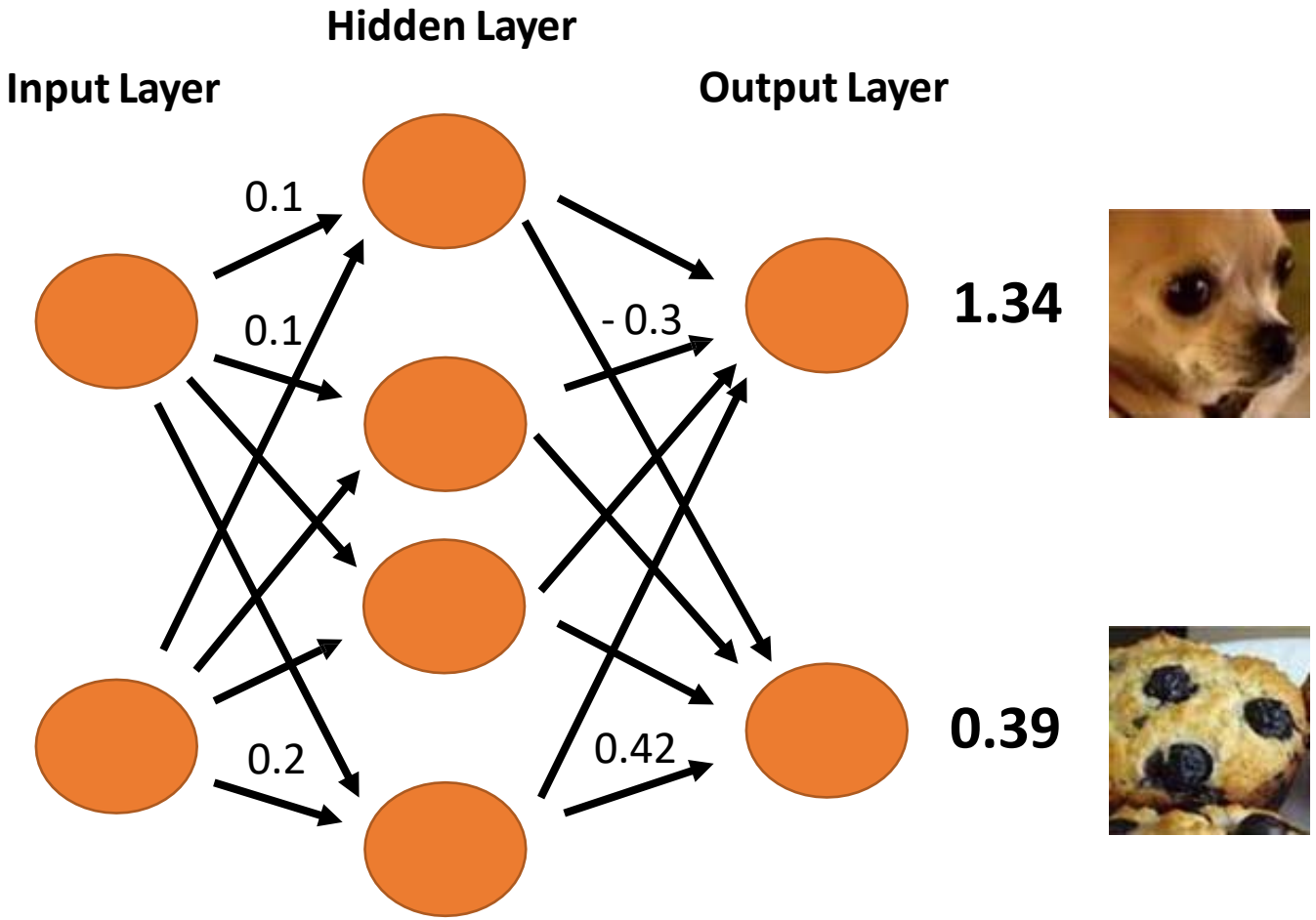
0

Artifical Neural Networks (ANNs)



5. How does our neural network learn?

We initialize our ANN with random weights and biases



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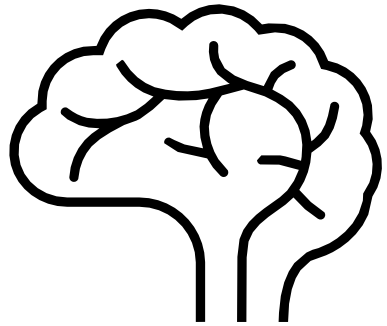


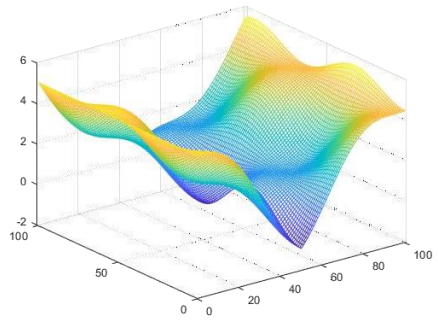
5. How does our neural network learn?

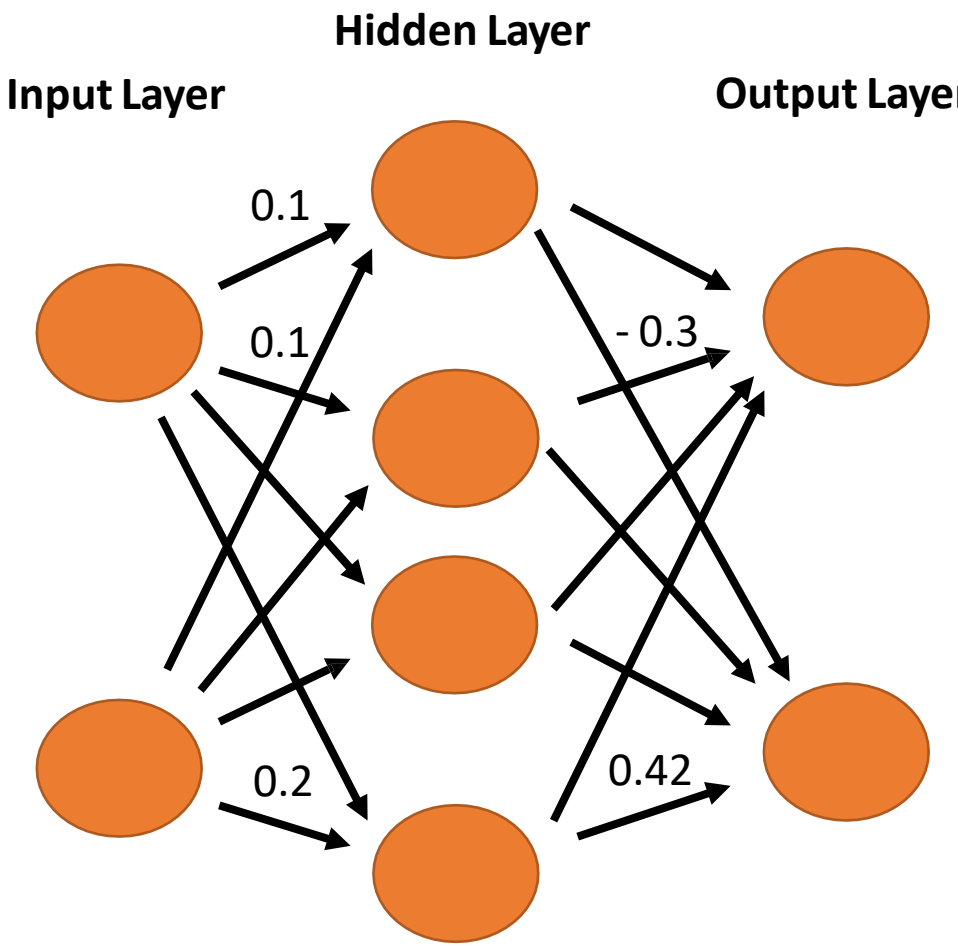
We calculate the loss function of our prediction

e.g. **Cross Entropy Loss**

$$L = -\log(\hat{y})$$

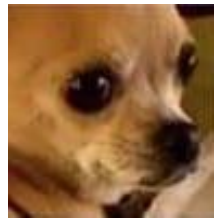
We use Gradient Descent to gradually approach the optimal weights and biases that minimize our loss function





SoftMax → training
ArgMax → test (application)

1.34



.72

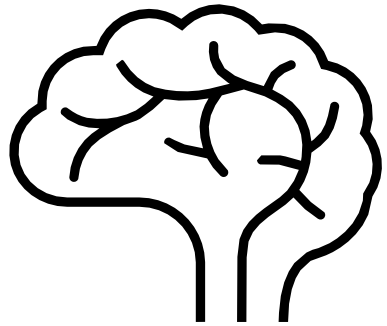
SoftMax

transforms the output values into „probabilities" for each category

0.39

.28

Artifical Neural Networks (ANNs)



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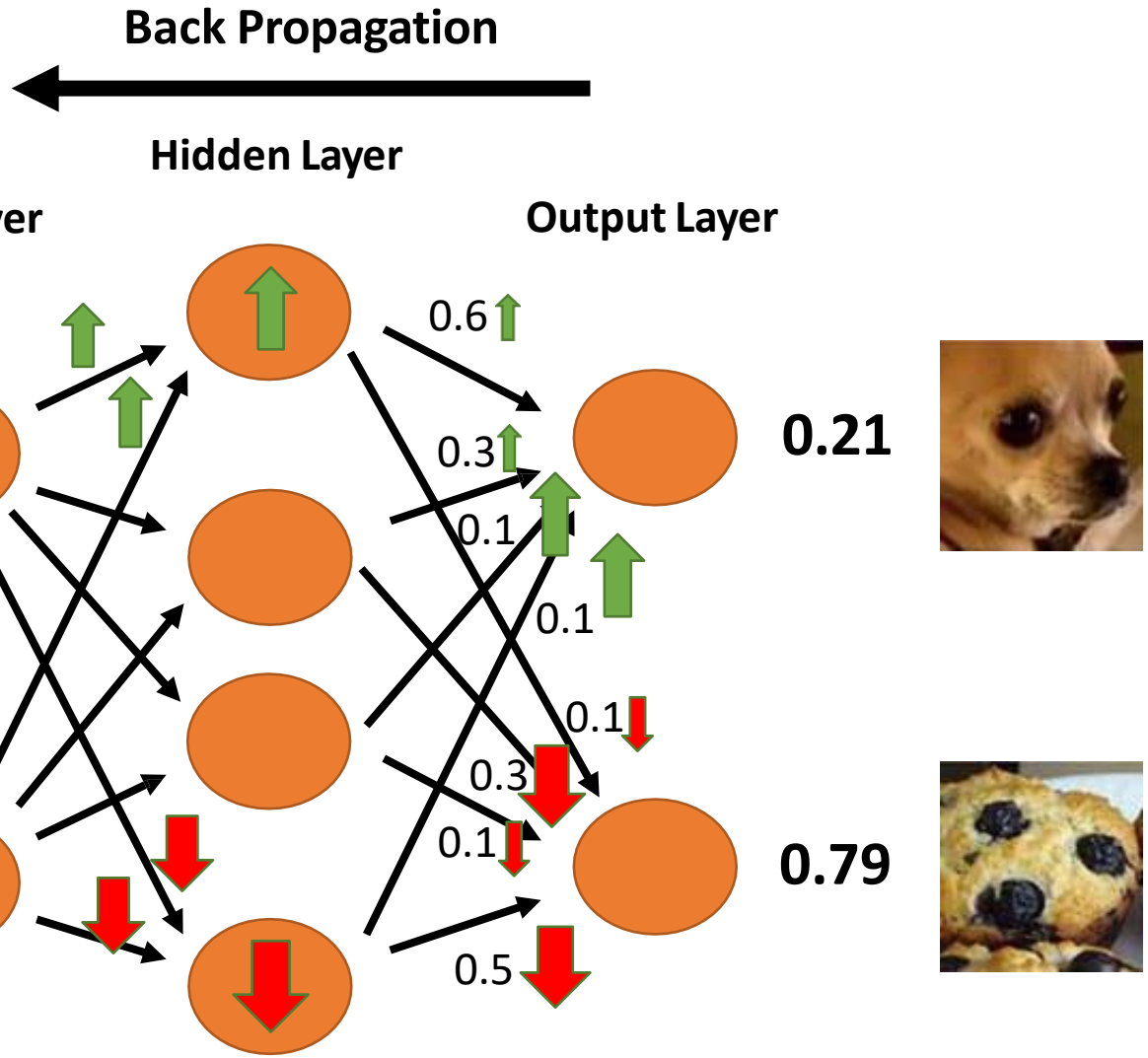
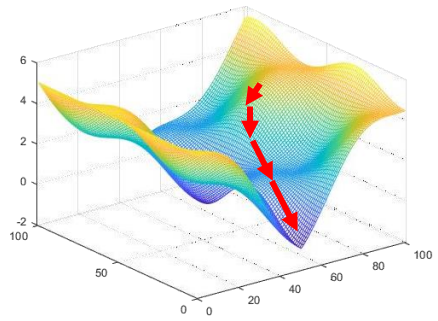


We adjust our weights and biases after each step



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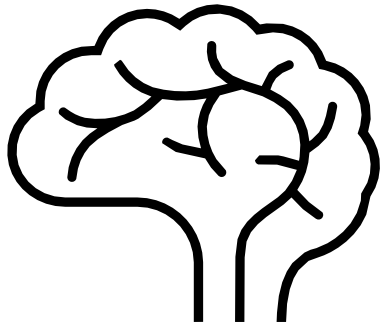
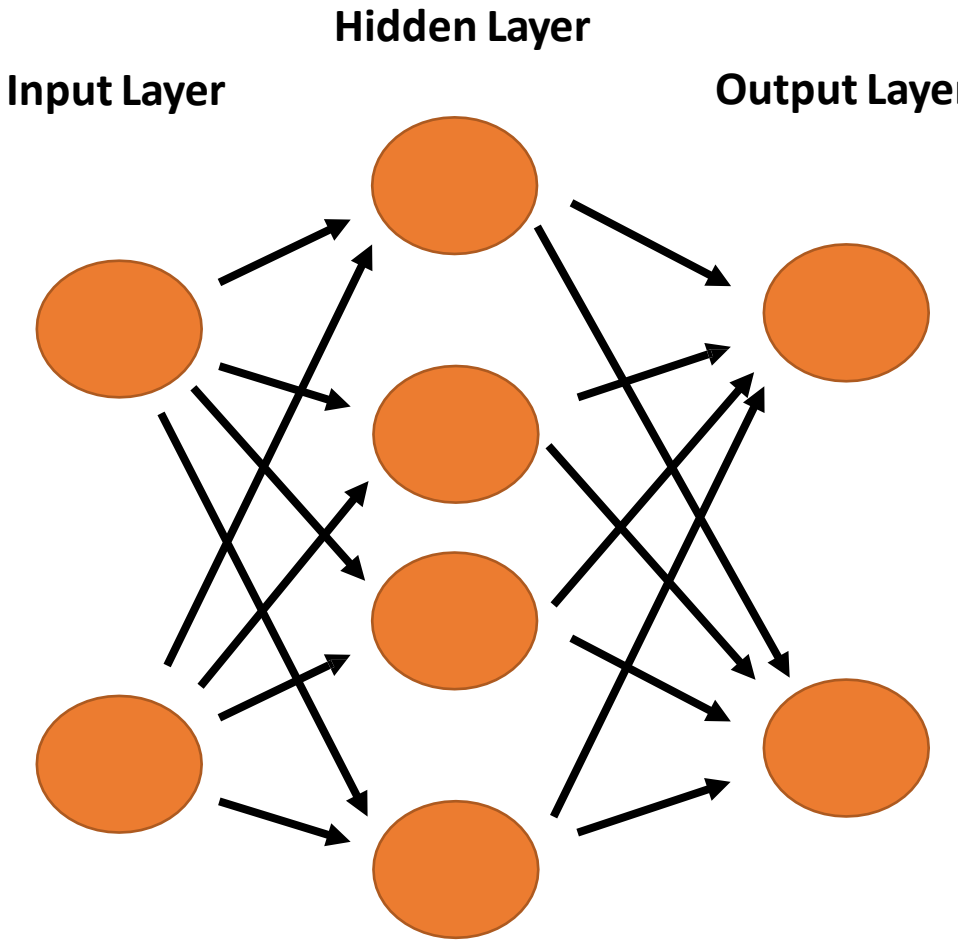


5. How does our neural network learn?

Special feature of training the ANNs:

Usually, we do not use the complete training dataset for each training step, but only a small subset, so-called **batches**



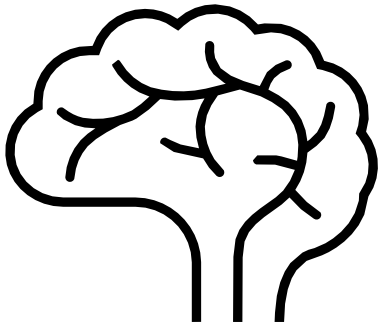
Pros:

We save resources, can train much faster and still get a good estimate of Gradient Descent!

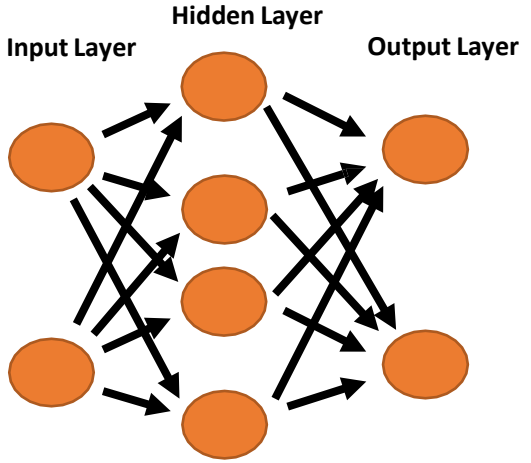
Cons:

We don’t know the optimal **batch size**!

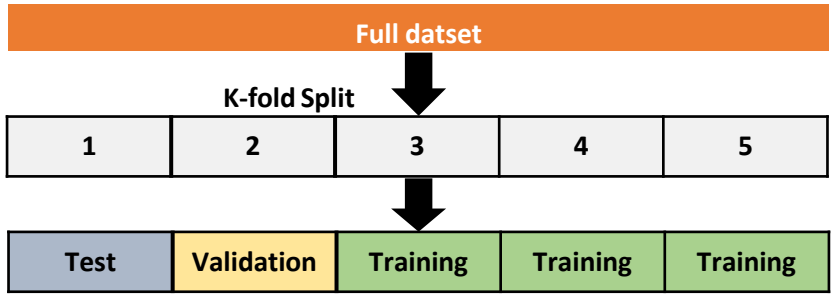
Artifical Neural Networks (ANNs)



6. We train our neural network in the same way as we trained other algorithms



Training / Test Splits



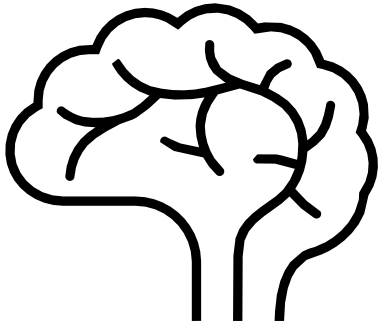
Hyperparameter Optimization

- Weight initializations
- Number of epochs
- Batch size
- Number of layers / neurons
- Activation function
- …

Regularization

- L1/L2
- Dropout
- Batch normalization
- Early stopping
- …

Representation Learning



So far we have chosen model features by ourselves....

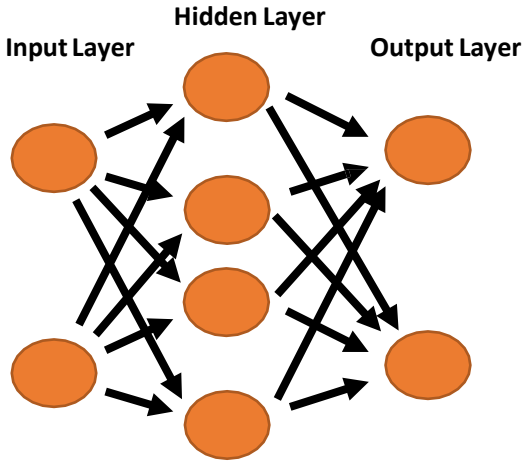
Feature Engineering

Which features, and in what form, can we use to train our algorithm?

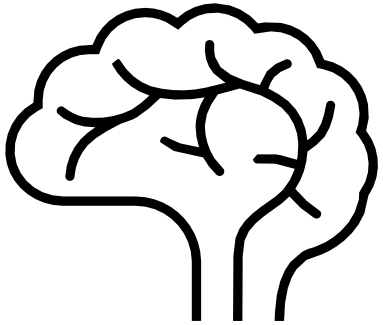
HOG_Pixel_1	HOG_Pixel_2	…	Red_Bin1	Red_Bin2	…
…	…	…	…	…	…
…	…	…	…	…	…
…	…	…	…	…	…
…	…	…	…	…	…

Representation Learning

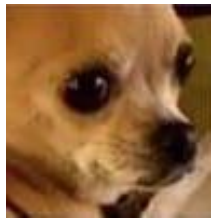
Idea: We feed our raw data into the neural network, and it decides which features to use on its own



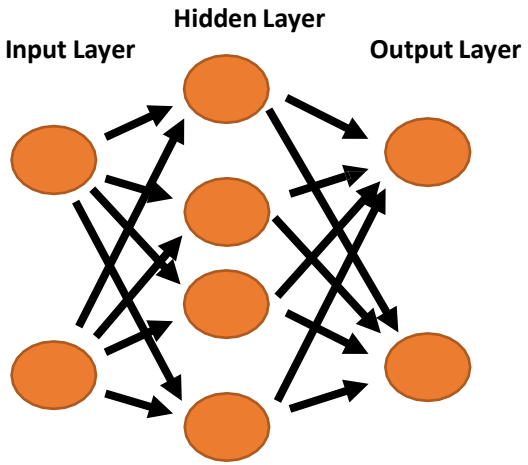
Representation Learning



… now we let the ANN itself learn which features to use from the raw data.



HOG_Pixel_1	HOG_Pixel_2	…	Red_Bin1	Red_Bin2	…
…	…	…	…	…	…
…	…	…	…	…	…
…	…	…	…	…	…
…	…	…	…	…	…



We directly imput single pixels into the ANN