Neural Networks

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Reference: *Hands-On Machine Learning with Scikit-Learn and TensorFlow* by Aurélien Géron (O'Reilly). Copyright 2017 Aurélien Géron, 978-1-491-96229-9.

Introduction

- YouTube Video: *But what *is* a Neural Network?* from 3Blue1Brown

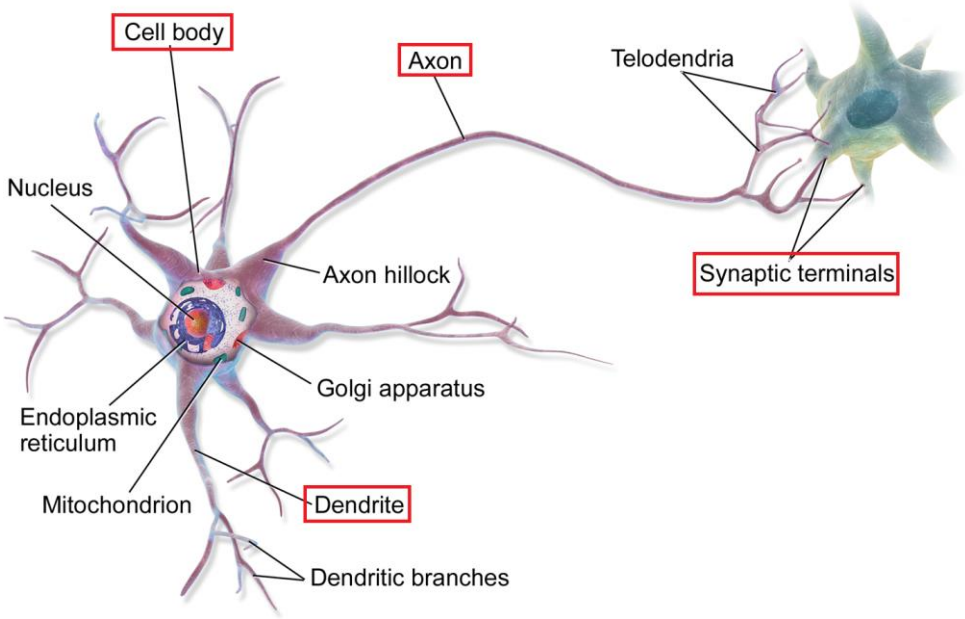
https://youtu.be/aircAruvnKk

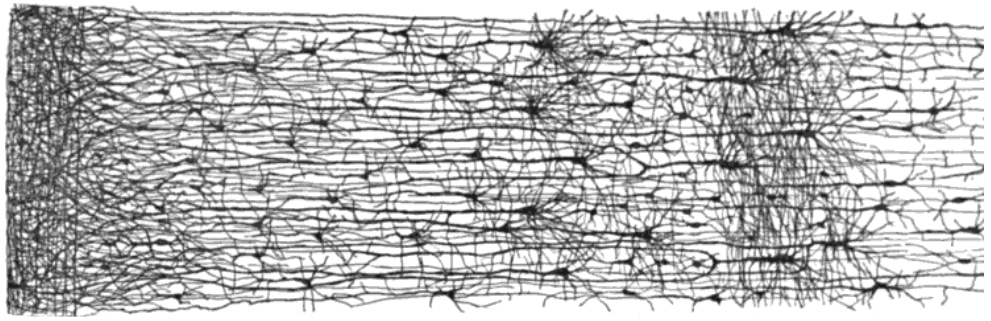
Outline

1. Introduction
2. The perceptron
3. Multi-layer perceptron
4. Fine-tuning neural network hyperparameters
5. Exercises

1. Introduction

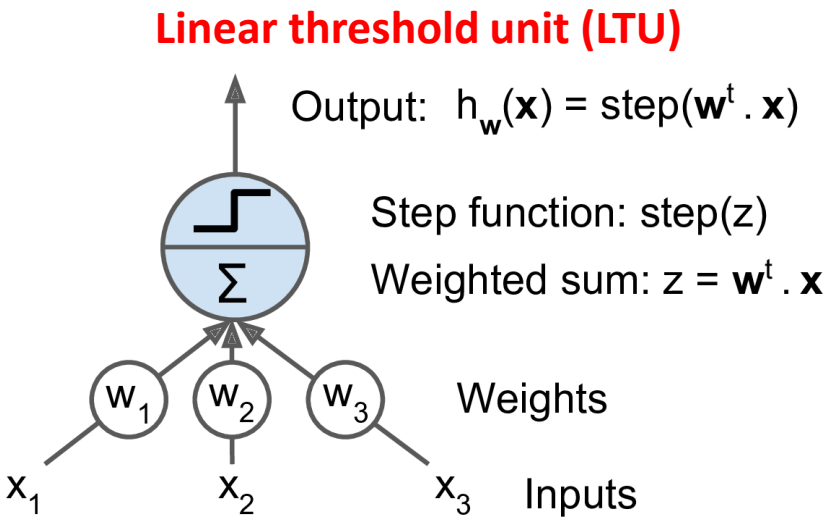
- *Artificial neural networks* (ANNs) are inspired by the brain's architecture.
- First suggested in 1943. Is now flourishing due to the availability of:
  - Data
  - Computing power
  - Better algorithms





2. The Perceptron

- The *Perceptron* is a simple ANN, invented in 1957 and can perform linear binary classification or regression.

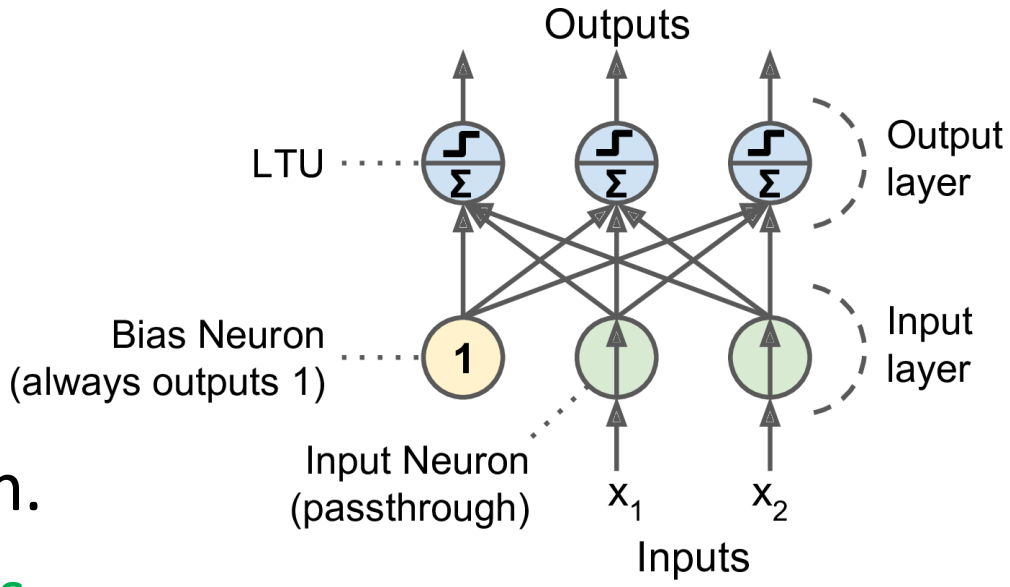


- Common step functions:

$$\text{heaviside}\,(z) = \begin{cases} 0 & \text{if } z < 0 \\ 1 & \text{if } z \geq 0 \end{cases} \qquad \text{sgn}\,(z) = \begin{cases} -1 & \text{if } z < 0 \\ 0 & \text{if } z = 0 \\ +1 & \text{if } z > 0 \end{cases}$$

2. The Perceptron

- The Perceptron has an *input layer* with *bias* and *output layer*.
- With multiple output nodes, it can perform multiclass classification.
- Hebbian learning "Cells that fire together, wire together."



$$w_{i,j}^{(\text{next step})} = w_{i,j} + \eta\left(y_j - \hat{y}_j\right)x_i$$

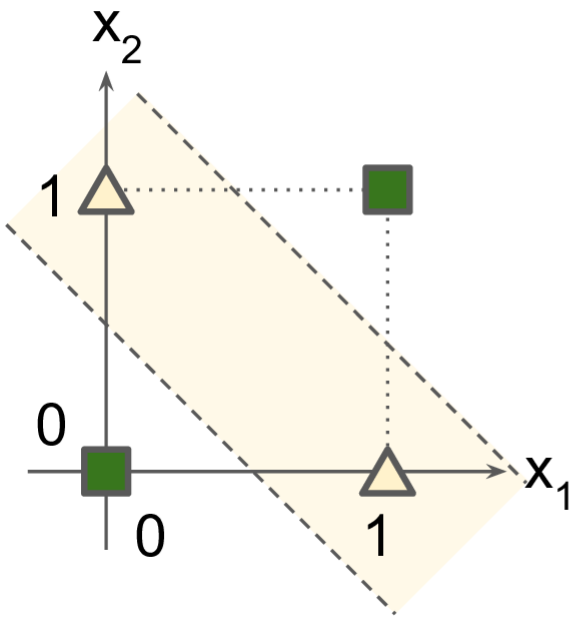
2. The Perceptron

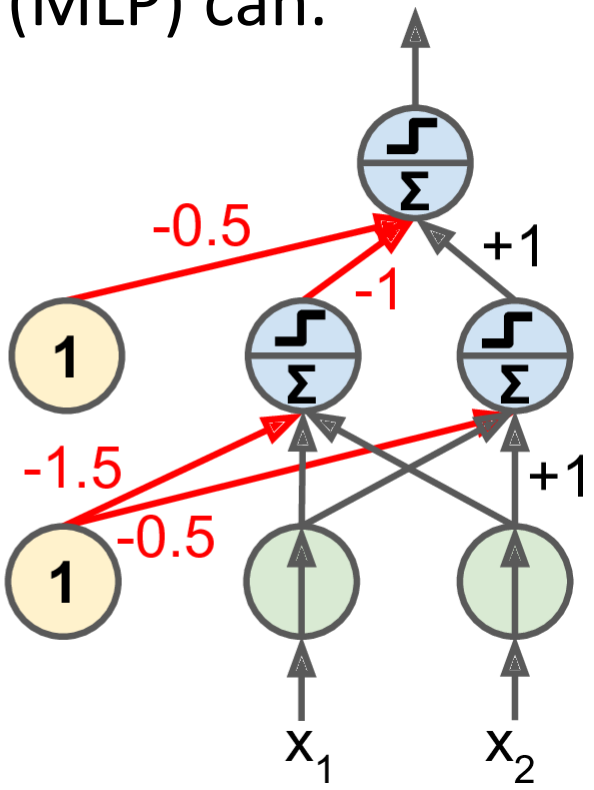
- Scikit-Learn provides a perceptron class.

```
import numpy as np
from sklearn.datasets import load_iris
from sklearn.linear_model import Perceptron

iris = load_iris()
X = iris.data[:, (2, 3)]  # petal length, petal width
y = (iris.target == 0).astype(np.int)  # Iris Setosa?

per_clf = Perceptron(random_state=42)
per_clf.fit(X, y)

y_pred = per_clf.predict([[2, 0.5]])
```

2. The Perceptron

- The perceptron cannot solve non-linear problems such as the XOR problem.
- The Multi-Layer Perceptron (MLP) can.





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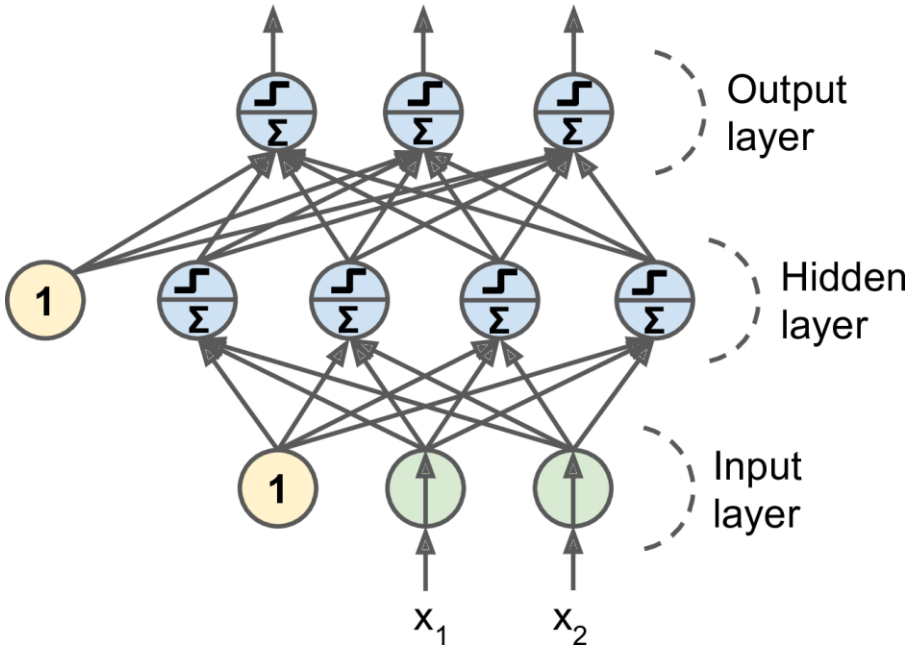
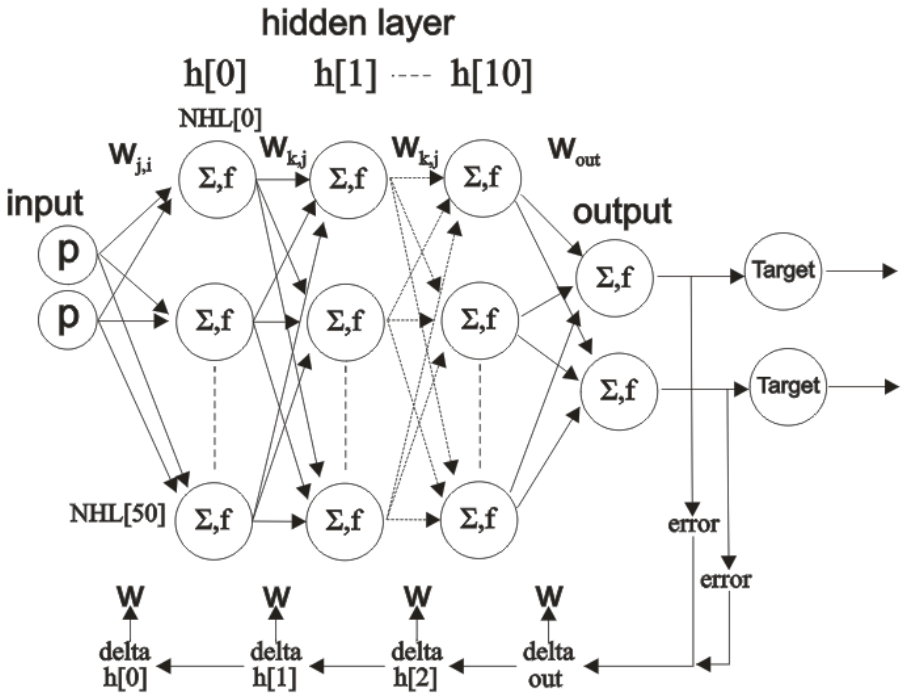
3. Multi-Layer Perceptron (MLP)

- An MLP is composed of a (pass-through) input layer, one or more layers of LTUs, called *hidden layers*, and a final layer of LTUs called the output layer.
- When an ANN has two or more hidden layers, it is called a *deep neural network* (DNN).



3. Multi-Layer Perceptron (MLP)

- Trained using the *backpropagation training algorithm*.
  - For each training instance the algorithm first makes a prediction (*forward pass*), measures the error,
  - then goes through each layer in reverse to measure the error contribution from each connection (*reverse pass*),
  - and finally slightly tweaks the connection weights to reduce the error (*Gradient Descent step*).



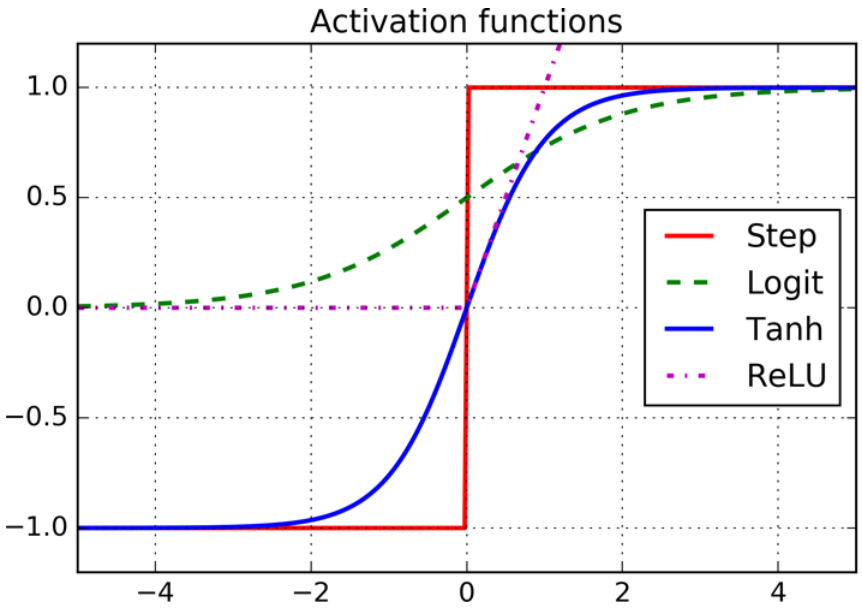
3. Multi-Layer Perceptron (MLP)

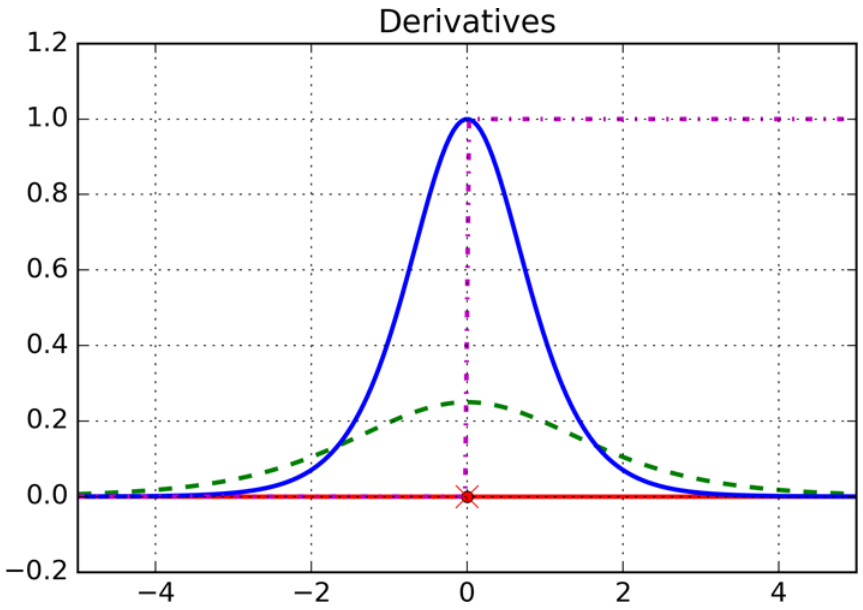
- **Common activation functions**: logistic, hyperbolic tangent, and rectified linear unit.

$$\sigma(z) = 1 / (1 + \exp(-z))$$

$$tanh\ (z) = 2\sigma(2z) - 1$$

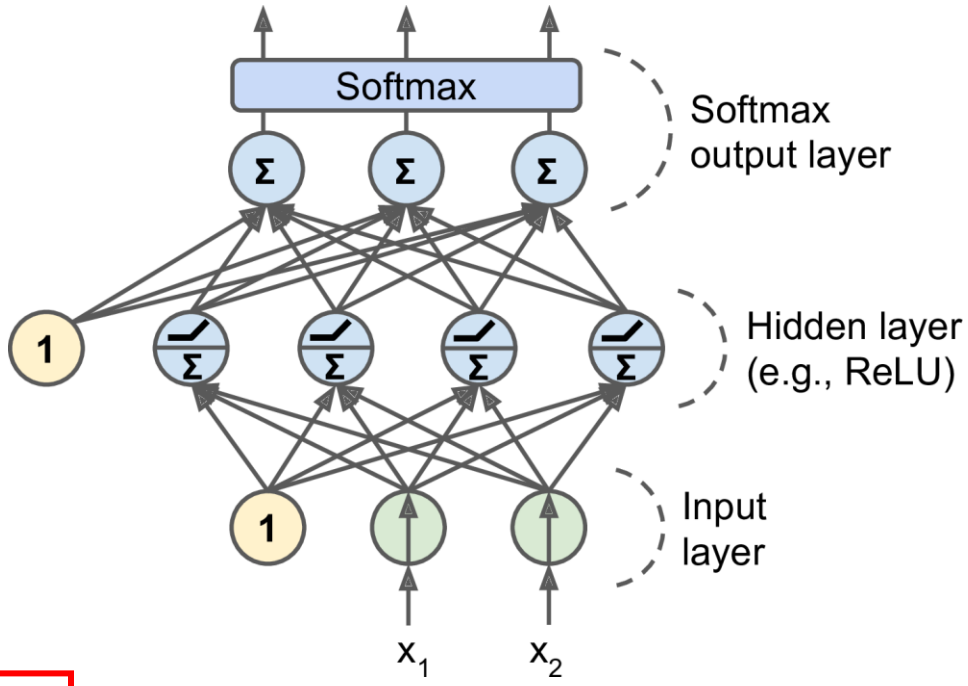
$$\mathrm{ReLU}\ (z) = \max\ (0, z)$$





3. Multi-Layer Perceptron (MLP)

- For classification, the output layer uses the *softmax function*.
- The output of each neuron corresponds to the estimated probability of the corresponding class.



$$\hat{p}_k = \sigma(\mathbf{s}(\mathbf{x}))_k = \frac{\exp\left(s_k(\mathbf{x})\right)}{\sum_{j=1}^{K} \exp\left(s_j(\mathbf{x})\right)}$$

$$\hat{y} = \underset{k}{\operatorname{argmax}}\ \sigma(\mathbf{s}(\mathbf{x}))_k$$

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4. Fine-Tuning Neural Network Hyperparameters

- Number of Hidden Layers
- Number of Neurons per Hidden Layer
- Activation Functions

Table 11-2. Default DNN configuration

Initialization	He initialization
Activation function	ELU
Normalization	Batch Normalization
Regularization	Dropout
Optimizer	Adam
Learning rate schedule	None

Summary

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Exercises

From Chapter 10, solve exercises:

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