Machine Learning (Artificial Neural Network)

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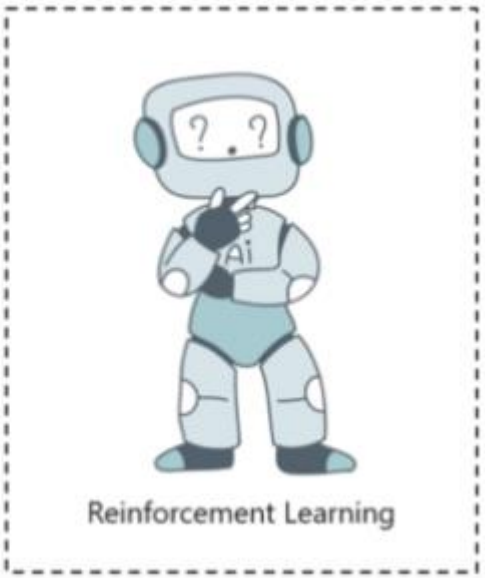
Types of Machine Learning

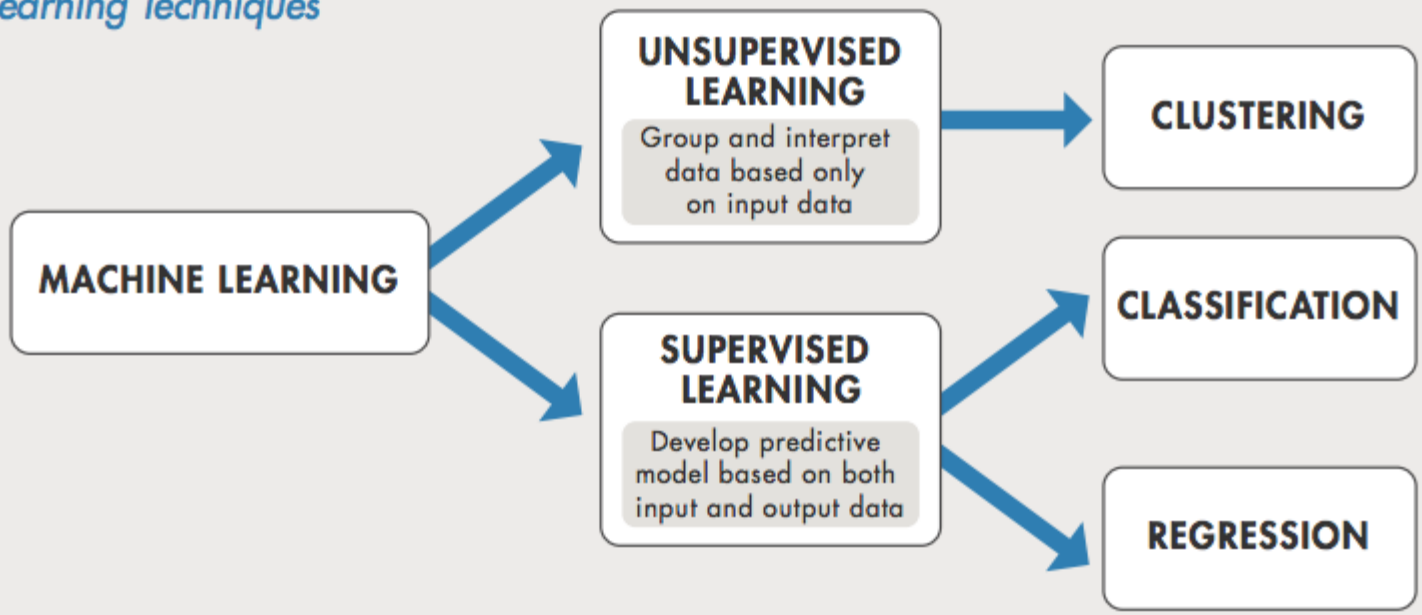
Supervised Learning

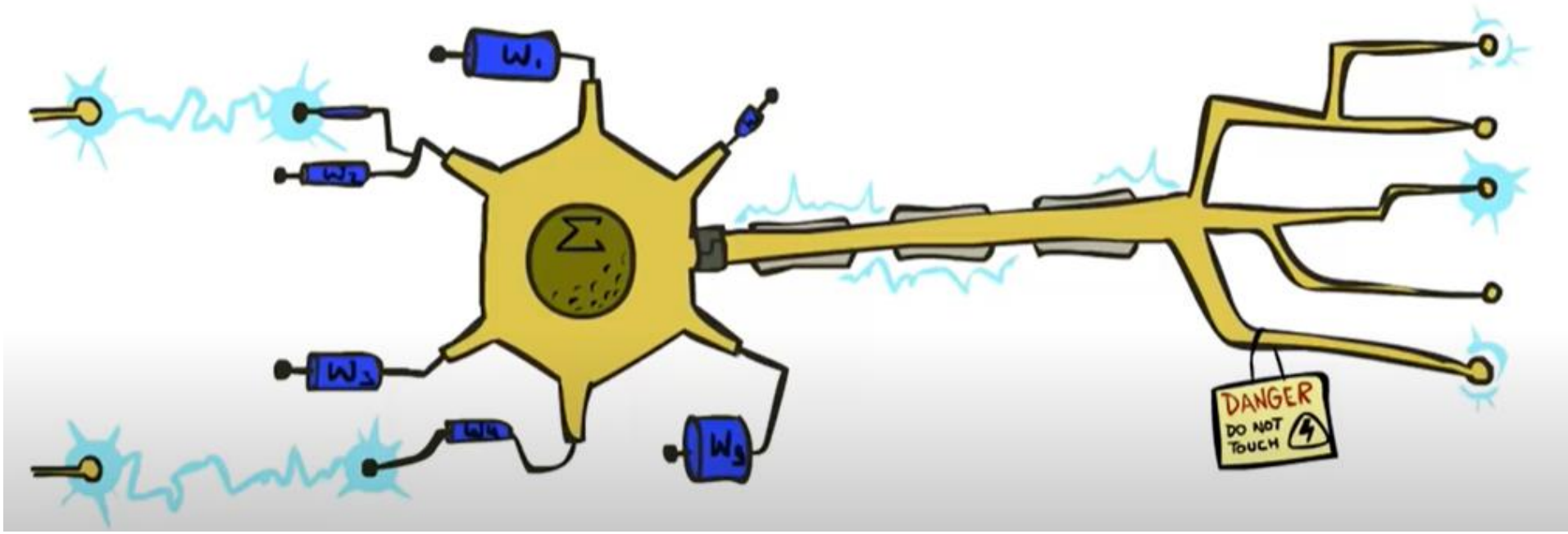
Unsupervised Learning



Reinforcement Learning

Machine Learning Techniques

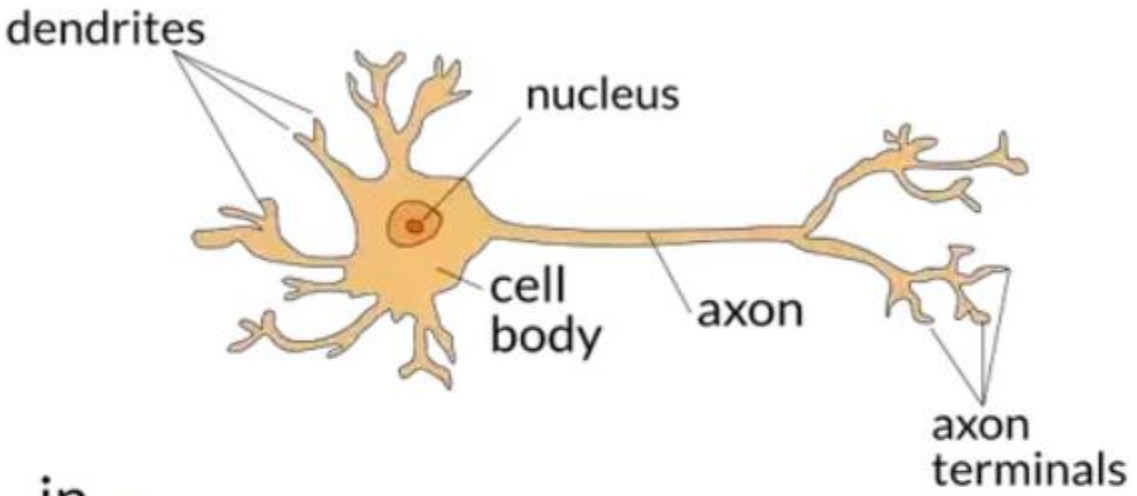


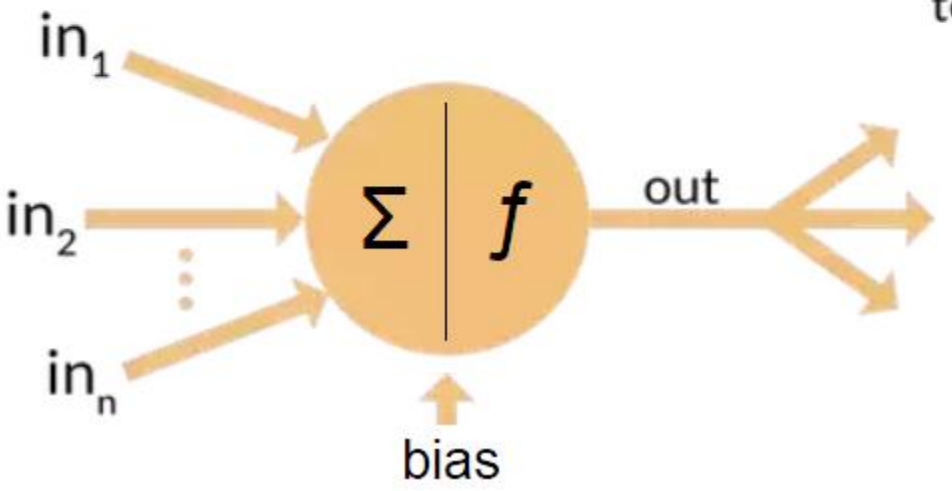


PERCEPTRON

Biological Neuron vs Perceptron

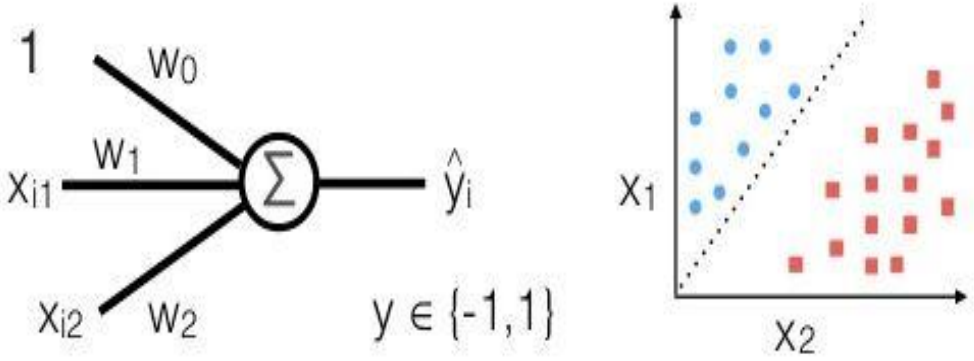
Soma	Neuron
Dendrite	Input
Axon	Output
Synapse	Weight





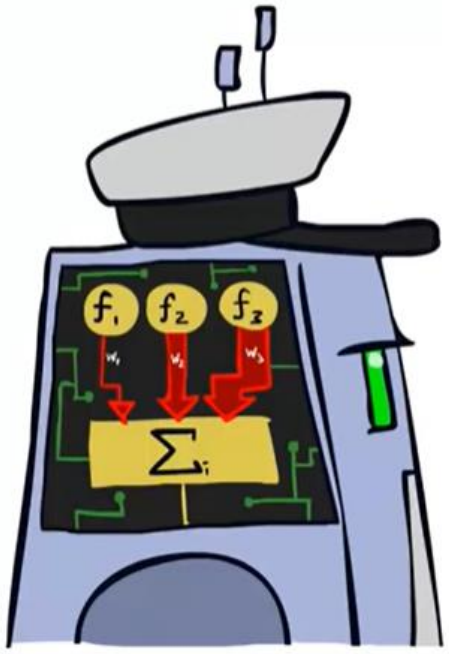
What is Perceptron

- It's a single node neural network that can take different inputs but produce only one output
- Perceptron is usually used to classify the data into two parts. Therefore, it is also known as a Linear Binary Classifier.

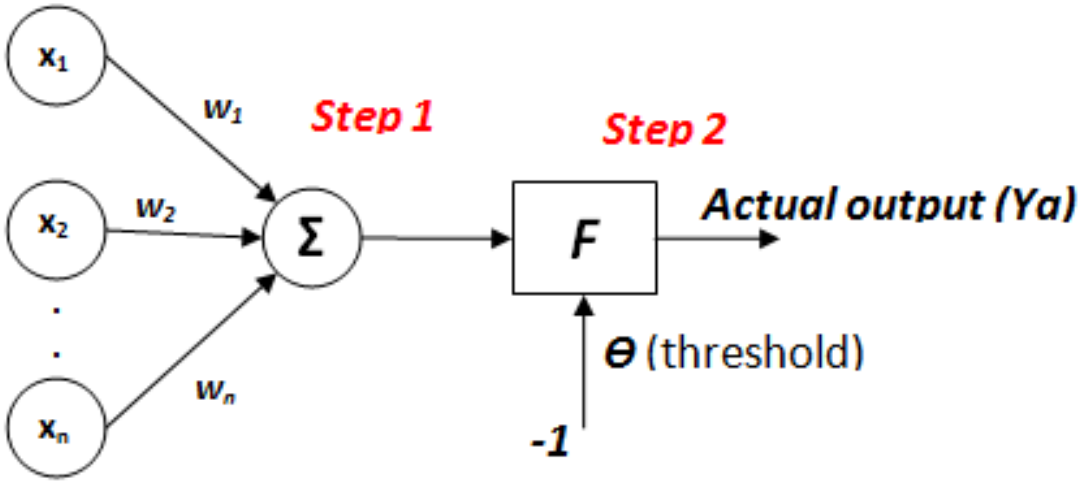


How does the neuron determine its output?

1. Computes the weighted sum input
2. Apply the value to the activation function (step, sign, sigmoid, linear)



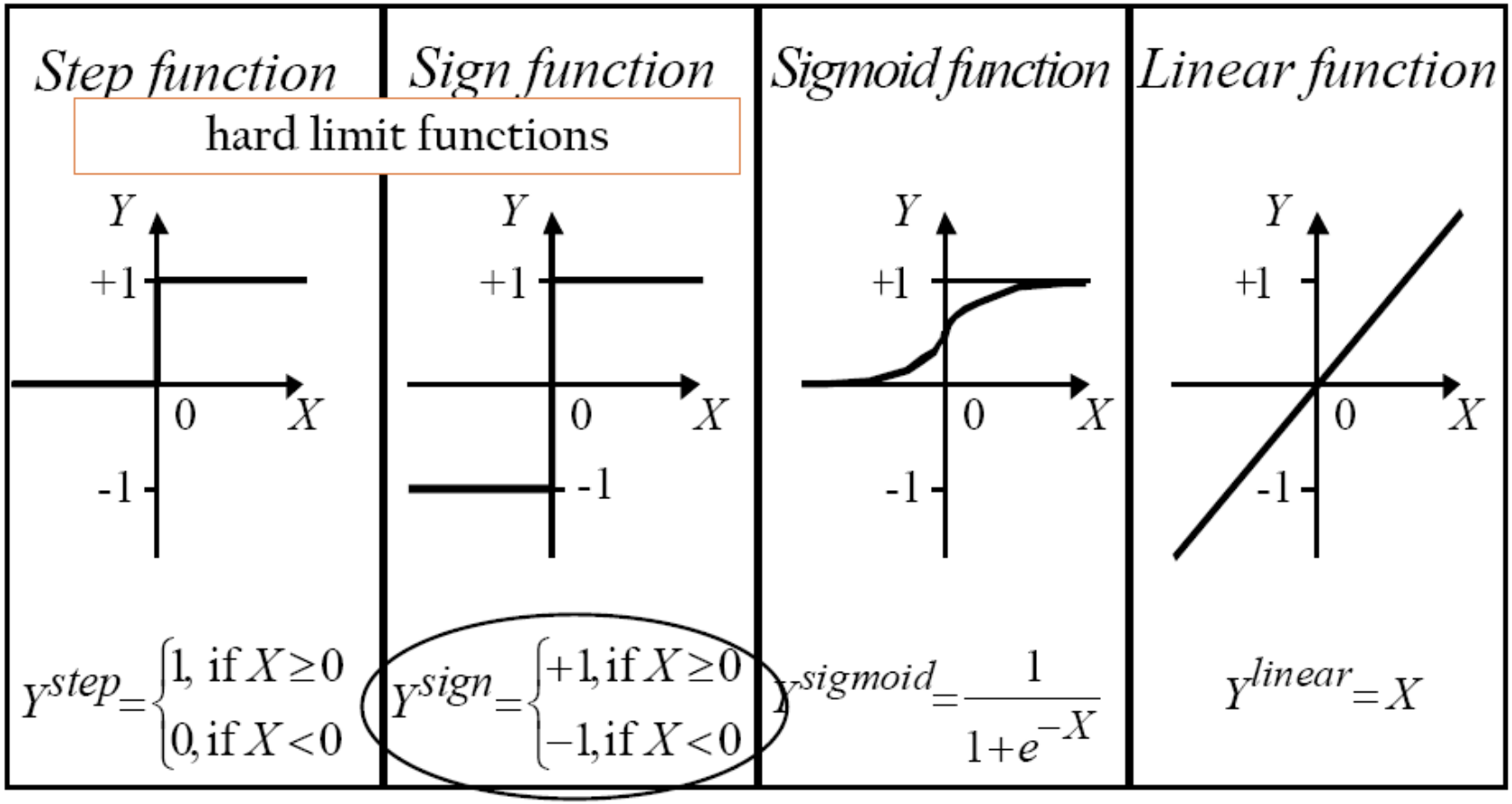
How does the neuron determine its output?



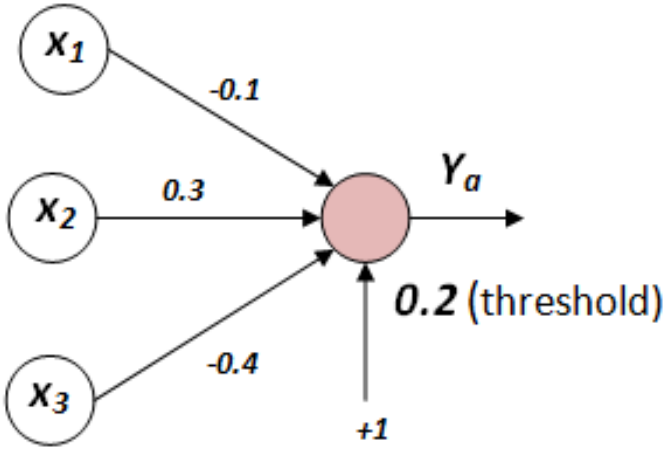
$$x_1w_1 + x_2w_2 + \ldots + x_nw_n$$

$$Ya = F\left(\sum_{i=1}^{n} x_i w_i - \theta\right)$$

Activation Functions



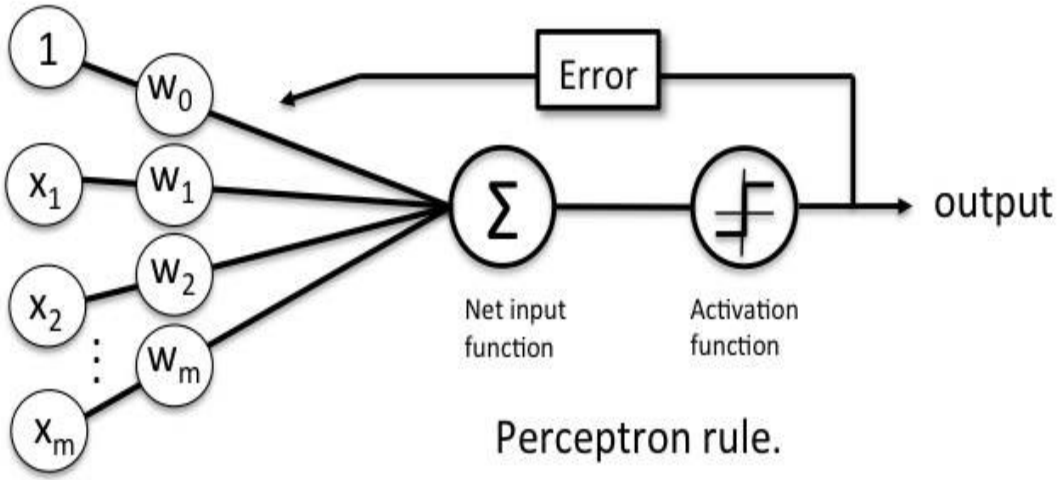
Example



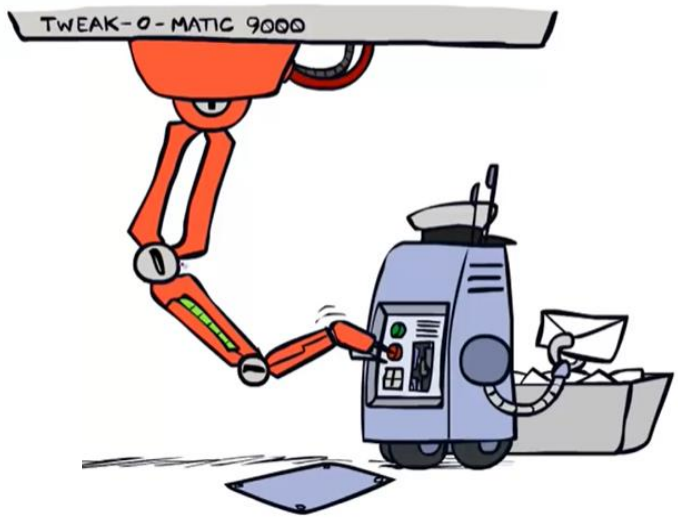
X1	X2	X3	Ya (step)
1	0	-1	1
-1	-1	0.5	0

How does a perceptron learn

- This is done by making small adjustments in the weights to reduce the difference between the actual and desired outputs of the perceptron



Perceptron rule.



Perceptron learn

- **Step 1: Initialization**
  - Set initial weights $w_1, w_2, \ldots, w_n$ and threshold to random numbers in the range [-0.5, 0.5]
- **Step 2: Activation**
  - Activate the perceptron by applying inputs $x_1(p)$, $x_2(p)$, $x_3(p)$, ...$x_n(p)$, and desired output $y_d(p)$ .Calculate the actual output at iteration $p = 1$

$$Y(p) = step\left[\sum_{i=1}^{n} x_i(p)w_i(p) - \theta\right]$$

  - where n is the number of the perceptron inputs, and step is a step activation function.

Perceptron learn

- **Step 3: Weight training**

  error e = $Y_{expected} - Y_{actual}$

  - Update the weights of the perceptron

$$w_i(p+1) = w_i(p) + \Delta w_i(p),$$

where Δw is the weight correction at iteration p. The weight correction is computed by the delta rule:

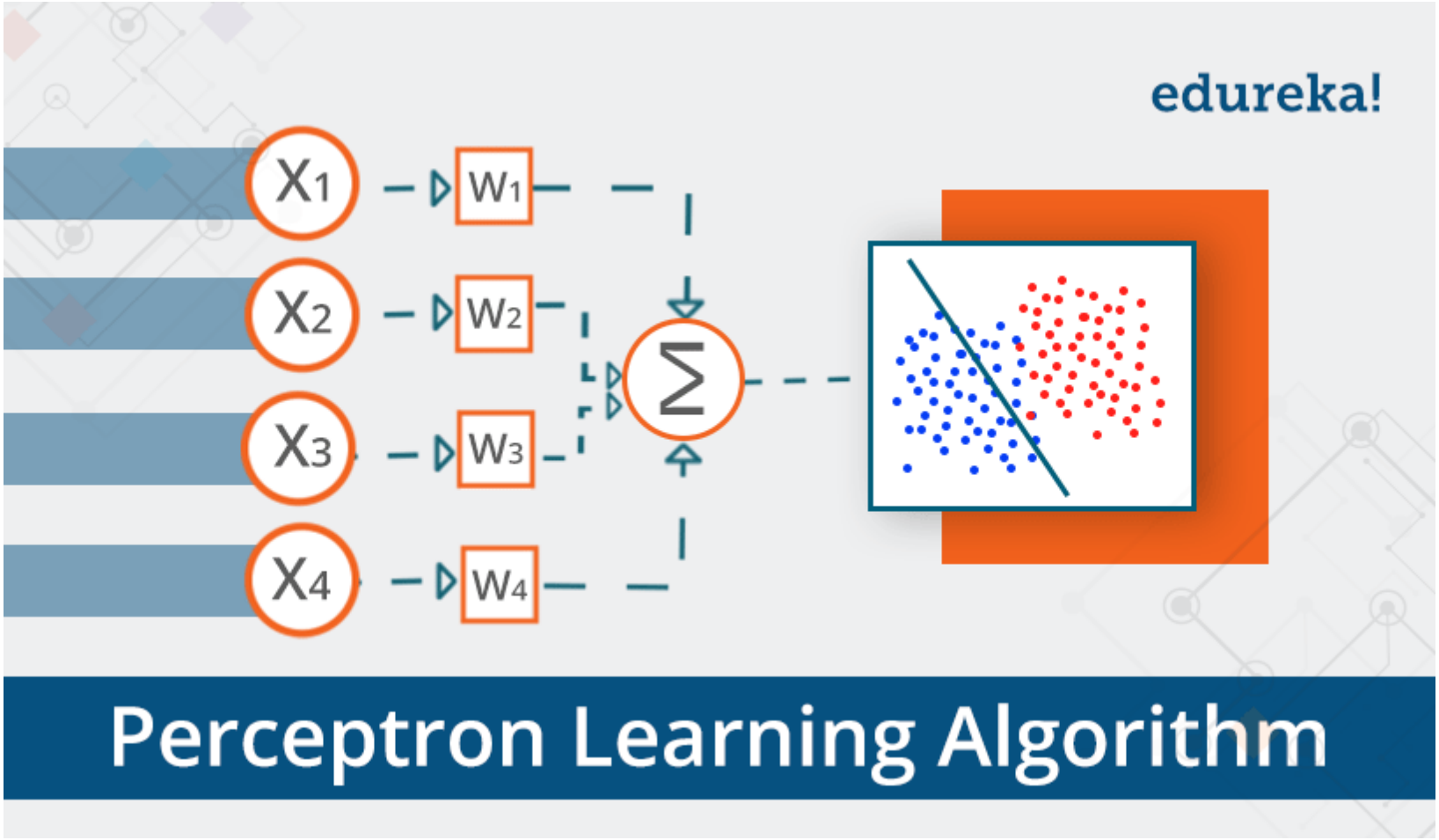
$$\Delta w_i(p) = \alpha \times x_i(p) \times e(p)$$

- **Step 4: Iteration**

  α is the *learning rate* (between 0 and 1)

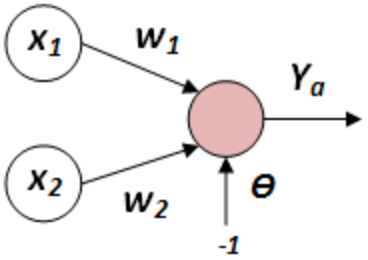
  - Increase iteration p by one, go back to Step 2 and repeat the process until convergence.

Perceptron learn



Perceptron Example – AND

- Train a perceptron to recognize logical AND



Epoch	Inputs		Desired output	Initial weights		Actual output	Error	Final weights	
	x_1	x_2	Y_d	w_1	w_2	Y	e	w_1	w_2
1	0	0	0	0.3	–0.1	0	0	0.3	–0.1
	0	1	0	0.3	–0.1	0	0	0.3	–0.1
	1	0	0	0.3	–0.1	1	–1	0.2	–0.1
	1	1	1	0.2	–0.1	0	1	0.3	0.0
2	0	0	0	0.3	0.0	0	0	0.3	0.0
	0	1	0	0.3	0.0	0	0	0.3	0.0
	1	0	0	0.3	0.0	1	–1	0.2	0.0
	1	1	1	0.2	0.0	1	0	0.2	0.0

Use threshold $\Theta = 0.2$ and learning rate $\alpha = 0.1$

Perceptron Example – AND

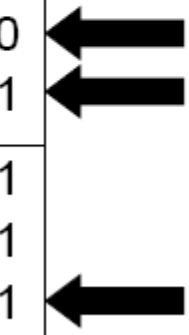
- Epoch 1
  - Iteration 1 (input X1=0; X2=0; Yd=0):
    - (0 * 0.3 + 0 * -0.1) -0.2 = -0.2
    - Ya =step(-0.2) =0
    - Error=Yd-Ya= 0
    - Δw1=0; Δw2=0;
  - Iteration 2 (input X1=0; X2=1; Yd=0):
    - (0 * 0.3 + 1 * -0.1) -0.2 = -0.3
    - Ya =step(-0.3) =0
    - Error=Yd-Ya= 0
    - Δw1=0; Δw2=0;

Perceptron Example – AND

- Iteration 3 (input X1=1; X2=0; Yd=0)
  - (1 * 0.3 + 0 * -0.1) -0.2 = +0.1
  - Ya =step(+0.1) =1
  - Error=Yd-Ya= -1
  - Δw1= 0.1 * 1 * -1= -0.1
  - W1(new) =w1(old)+ Δw1 =0.3-0.1 =**0.2**
  - **Δw2 =0**

Perceptron Example – AND

Epoch	Inputs		Desired output	Initial weights		Actual output	Error	Final weights	
	x_1	x_2	Y_d	w_1	w_2	Y	e	w_1	w_2
3	0	0	0	0.2	0.0	0	0	0.2	0.0
	0	1	0	0.2	0.0	0	0	0.2	0.0
	1	0	0	0.2	0.0	1	−1	0.1	0.0
	1	1	1	0.1	0.0	0	1	0.2	0.1
4	0	0	0	0.2	0.1	0	0	0.2	0.1
	0	1	0	0.2	0.1	0	0	0.2	0.1
	1	0	0	0.2	0.1	1	−1	0.1	0.1
	1	1	1	0.1	0.1	1	0	0.1	0.1



Perceptron Example – AND

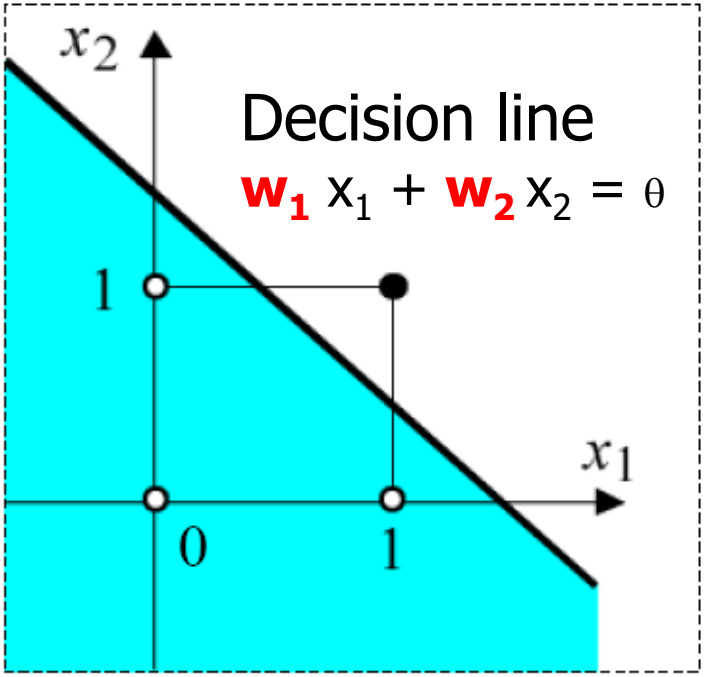
- Repeat until convergence
  - i.e. final weights do not change and *no error*

Epoch	Inputs		Desired output	Initial weights		Actual output	Error	Final weights	
	x_1	x_2	Y_d	w_1	w_2	Y	e	w_1	w_2
5	0	0	0	0.1	0.1	0	0	0.1	0.1
	0	1	0	0.1	0.1	0	0	0.1	0.1
	1	0	0	0.1	0.1	0	0	0.1	0.1
	1	1	1	0.1	0.1	1	0	0.1	0.1

Epoch refers to one cycle through the full training dataset.
Usually, training a **neural network** takes more than a few **epochs**

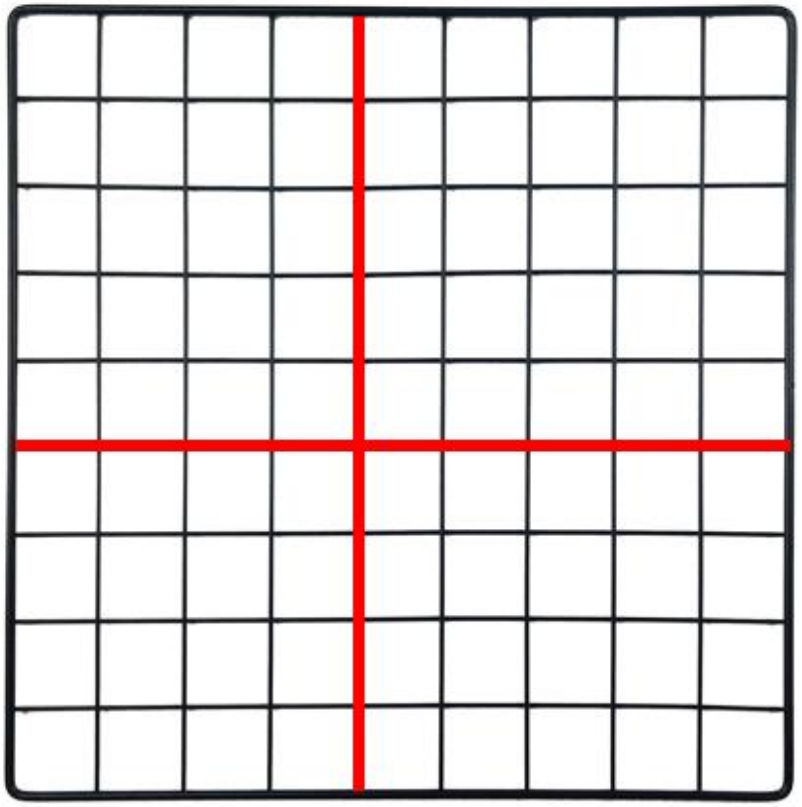
Summary

- Single perceptron can be trained to recognize any **linear separable function**
- Perceptron is able to represent a function only if there is some line that separates all the black dots from all the white dots

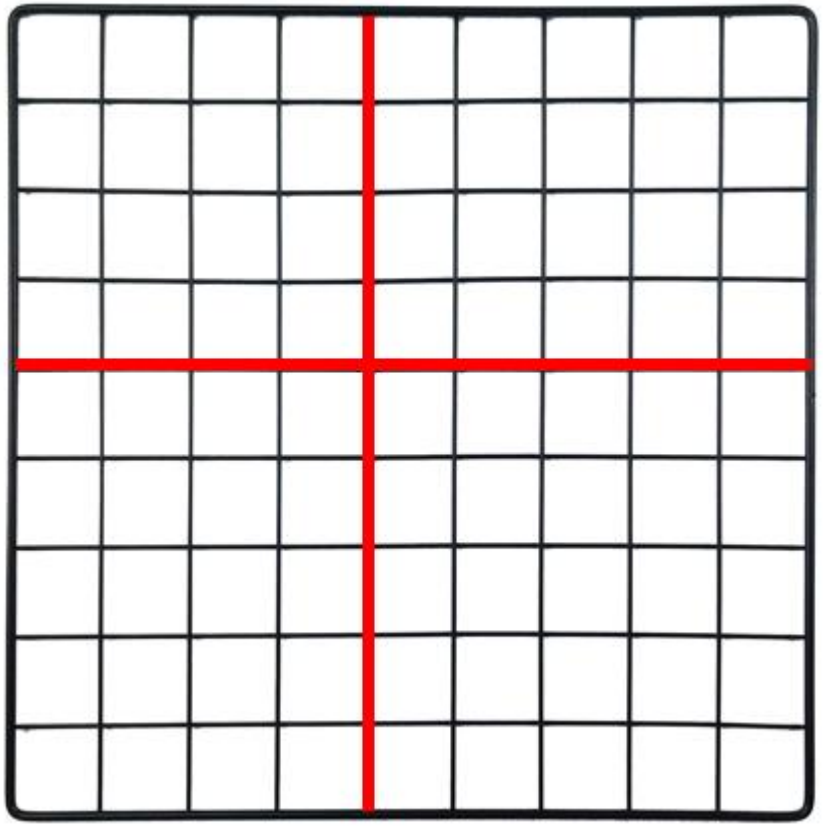


Drawing Line

$Y= 2x-2$



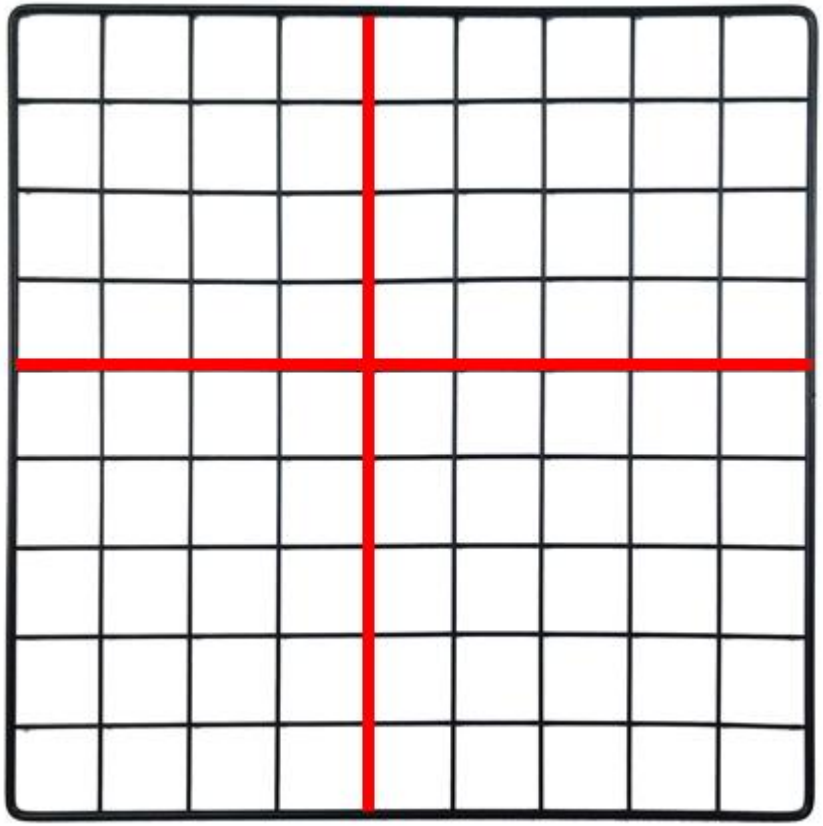
$Y= -\frac{1}{2}x+1$



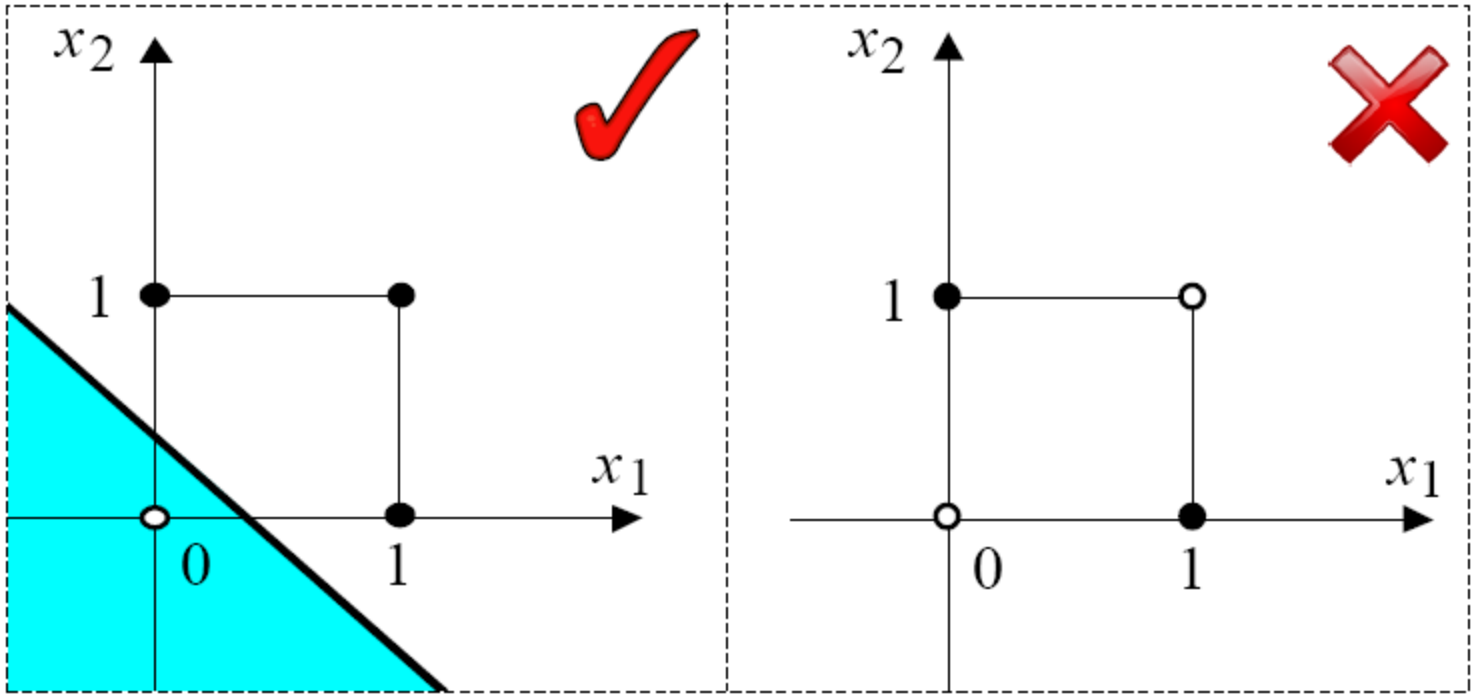
Drawing Line (AND example)

$$0.1X_1 + 0.1X_2 - 0.2 = 0$$

$$X_2 = -X_1 + 2$$

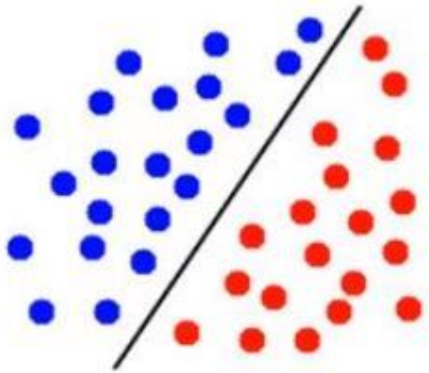


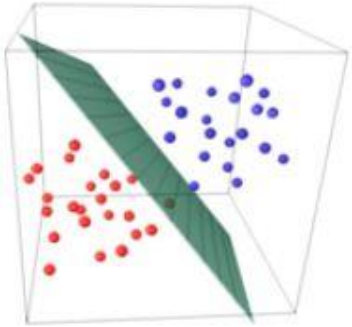
Summary



Summary

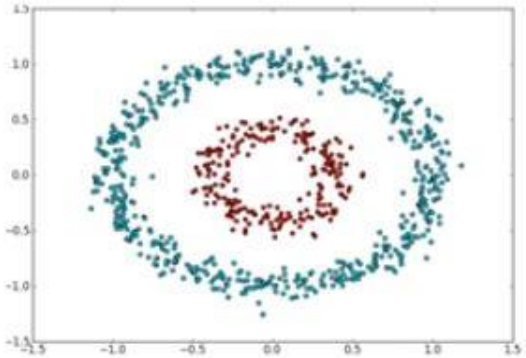
Linearly Separable

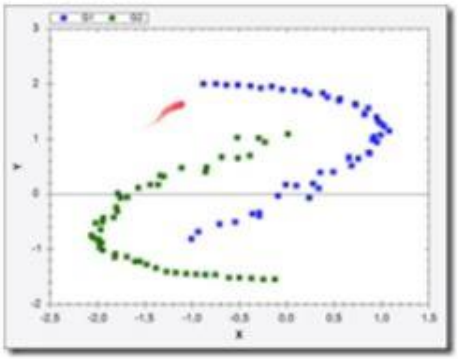




← 3D

Not Linearly Separable





Summary

- A Neural Network Playground - TensorFlow

Next Topic

- **Feed-forward neural network**