

INTRODUCTION TO DEEP LEARNING

Seminar @ UPC TelecomBCN Barcelona (3rd edition). 22-28 January 2020.



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Day 1 Lecture 3

The Perceptron



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Video lectures

Winter Seminar UPC TelecomBCN, 24 - 31 January 2017

Day 1 Lecture 2
The Perceptron

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Santiago Pascual

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Santiago Pascual, [DLSL 2017](#)

DEEP LEARNING
FOR ARTIFICIAL INTELLIGENCE

Master Course UPC ETSETB TelecomBCN Barcelona, Autumn 2018

Day 1 Lecture 2
The Perceptron

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Xavier Giro-i-Nieto, [DLAI 2018](#)

Outline

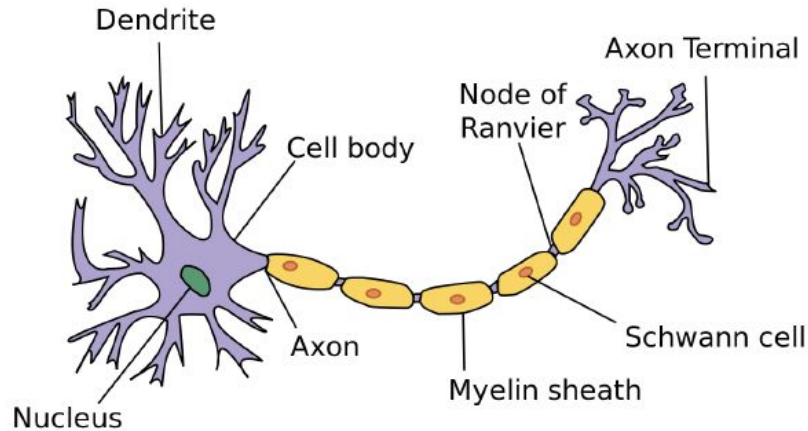
1. **Single neuron model (Perceptron)**
2. Regression
 - a. Linear regression
 - b. Logistic regression

Single neuron model (perceptron)

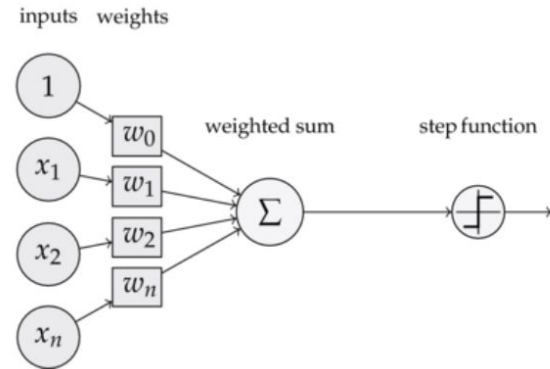
The Perceptron is seen as an **analogy** to a biological neuron.

Biological neurons fire an impulse once the sum of all inputs is over a threshold.

The perceptron acts like a switch (learn how in the next slides...).

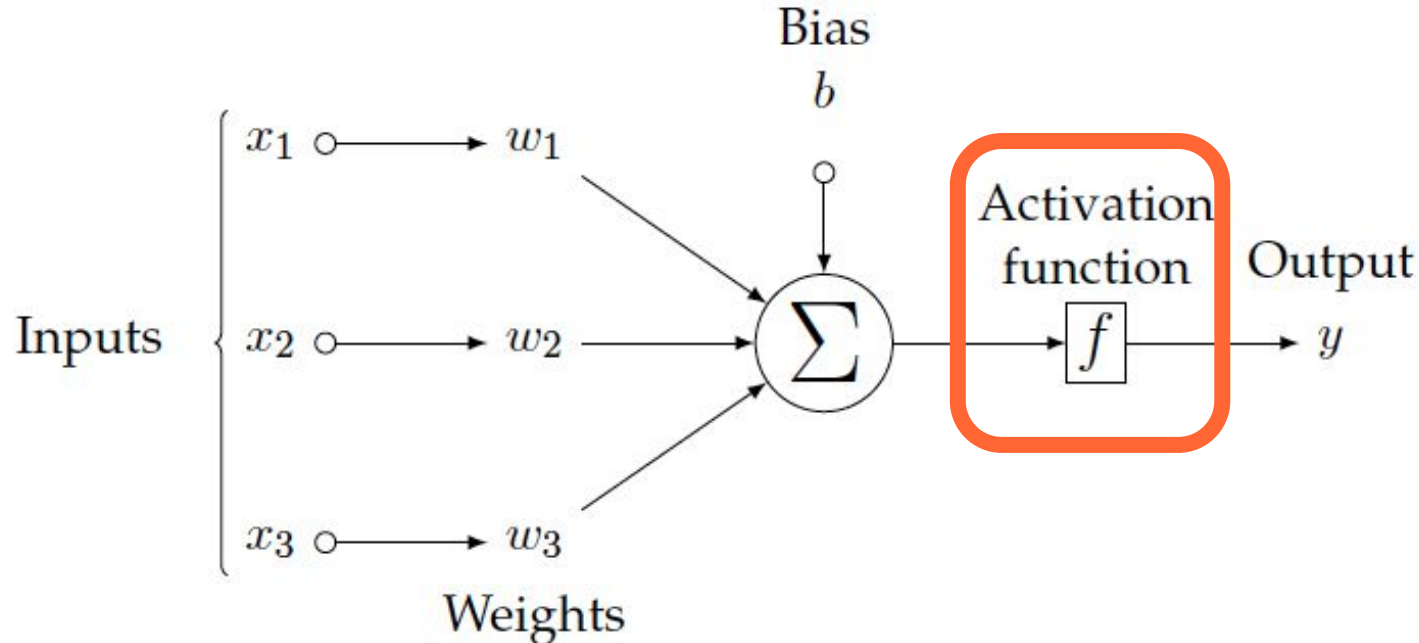


Rosenblatt's Perceptron (1958)

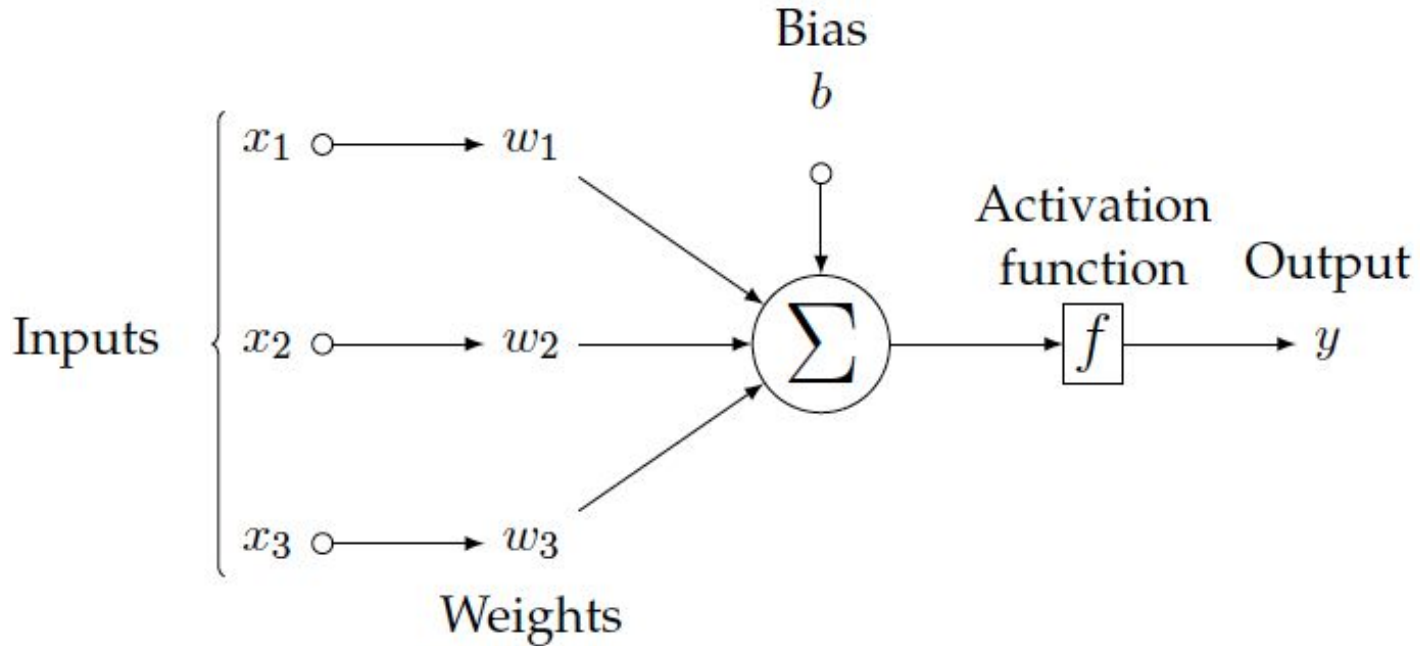


Single Neuron Model (Perceptron)

The perceptron can address both regression or classification problems, depending on the chosen **activation function**.

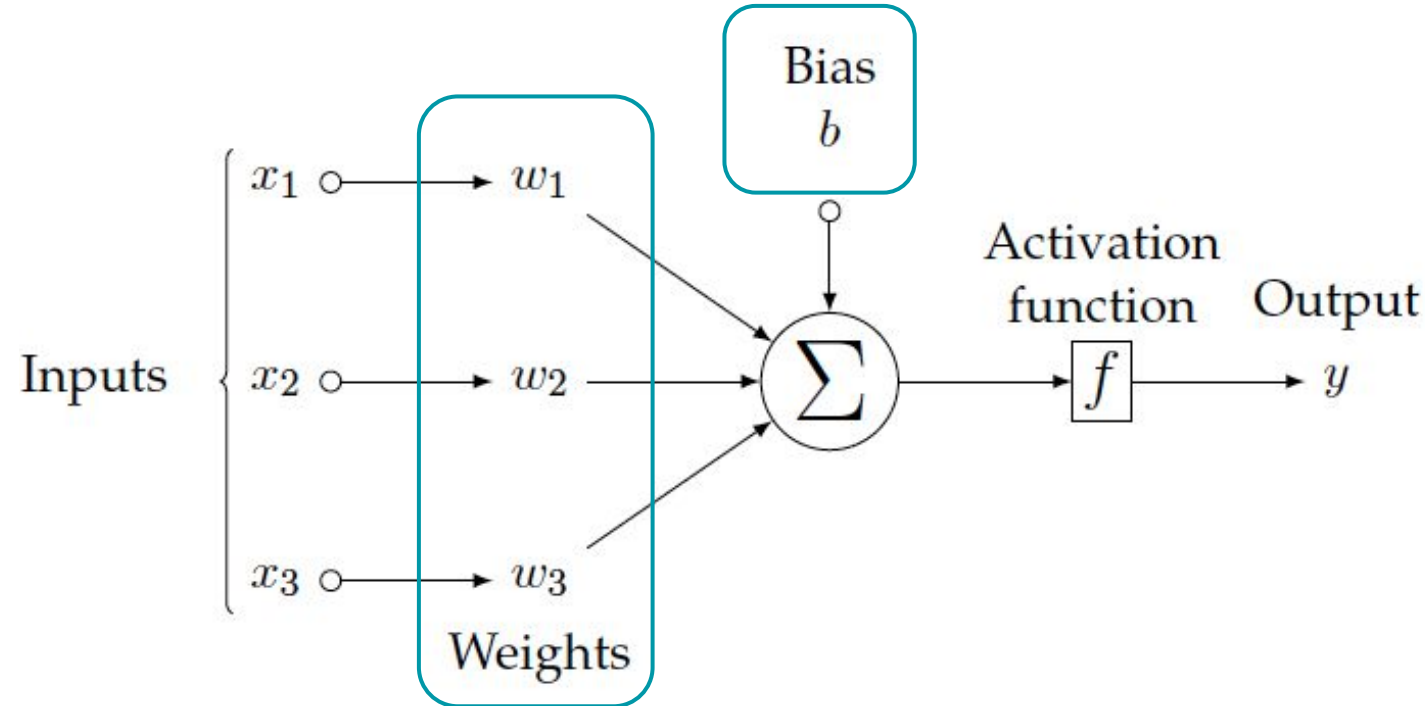


Single Neuron Model (Perceptron)



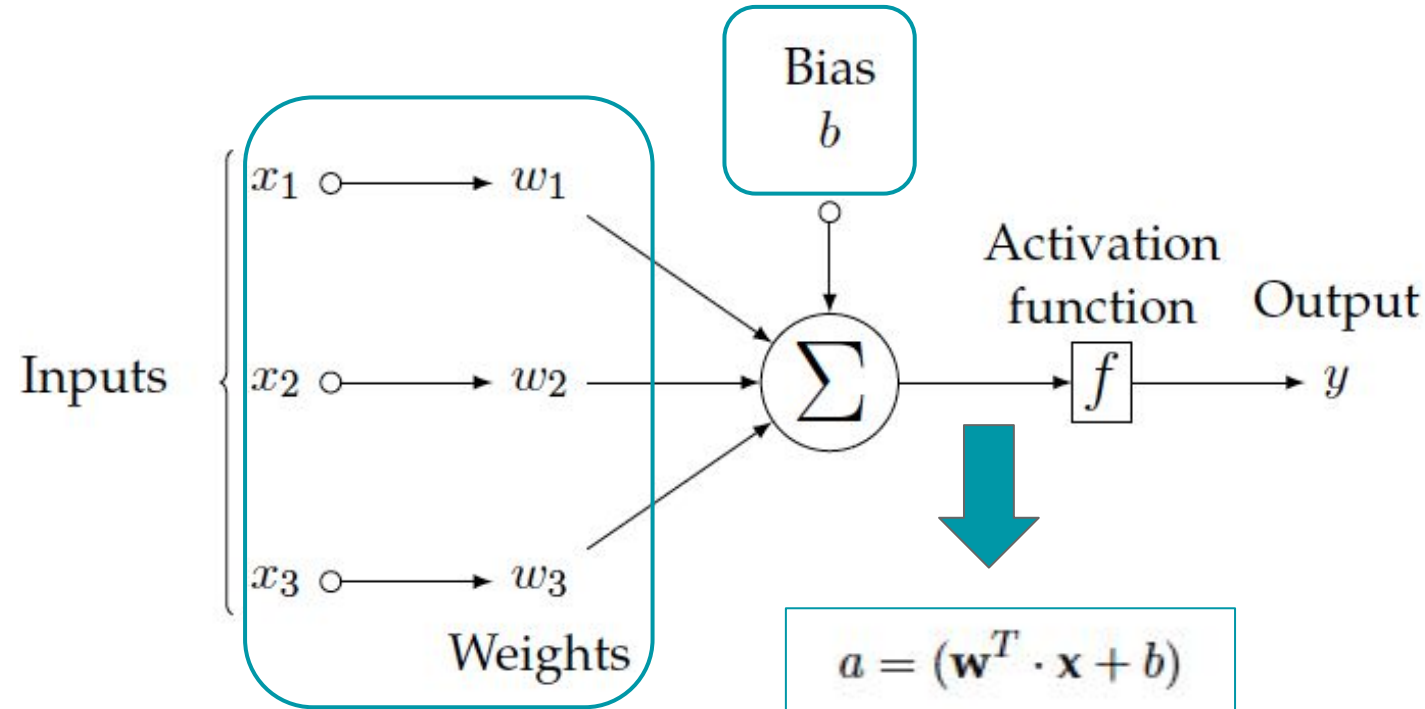
Single Neuron Model (Perceptron)

Weights and bias are the parameters that define the behavior. They must be estimated during training.



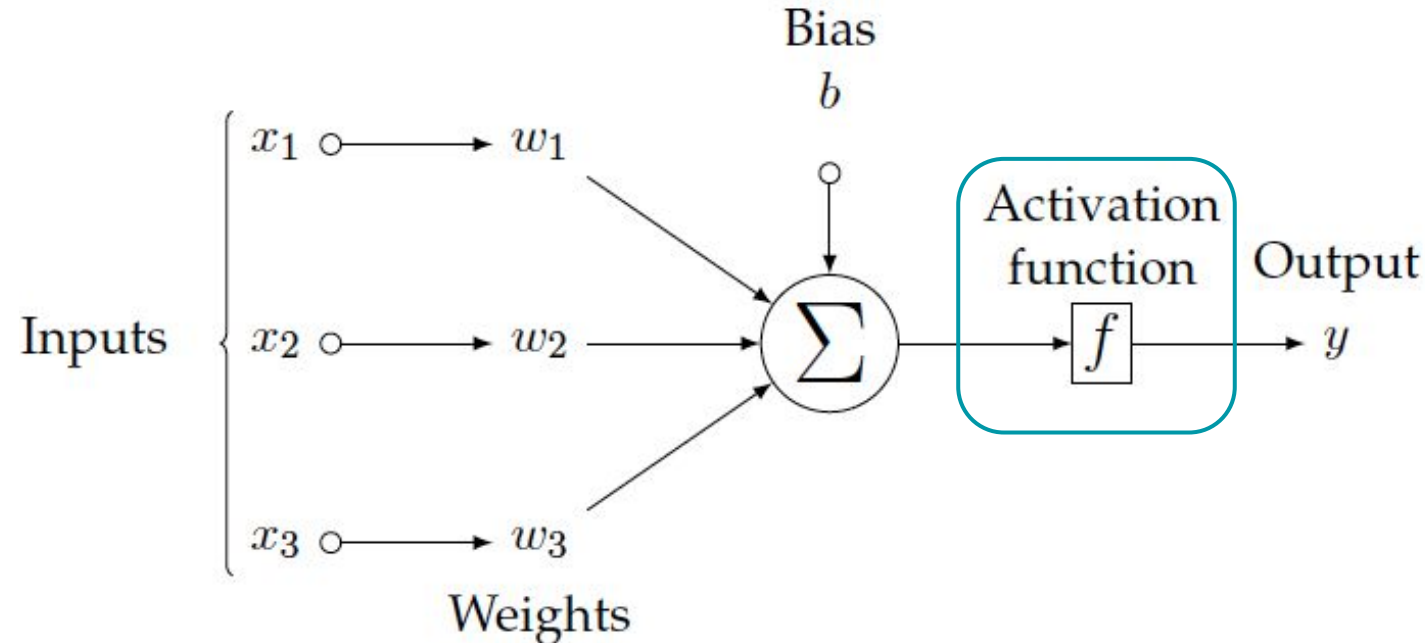
Single Neuron Model (Perceptron)

The output y is derived from a sum of the **weighted** inputs plus a **bias** term.



Single Neuron Model (Perceptron)

The **activation function** introduces non-linearities.



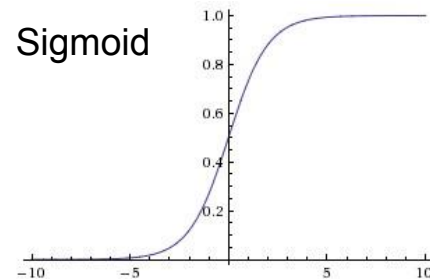
Single Neuron Model (Perceptron)

Desirable properties

- Mostly smooth, continuous, differentiable
- Fairly linear

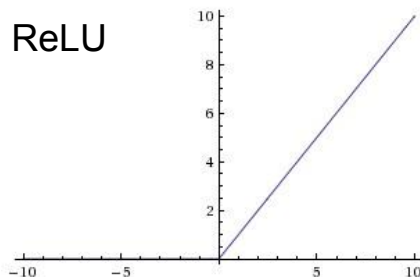
Common nonlinearities

- Sigmoid
- Tanh
- ReLU = $\max(0, x)$



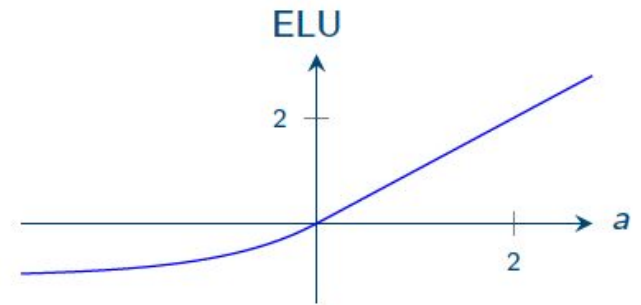
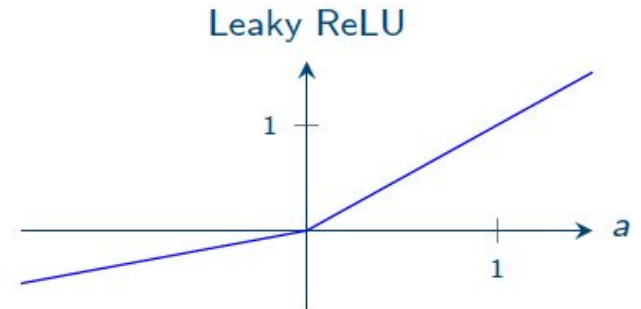
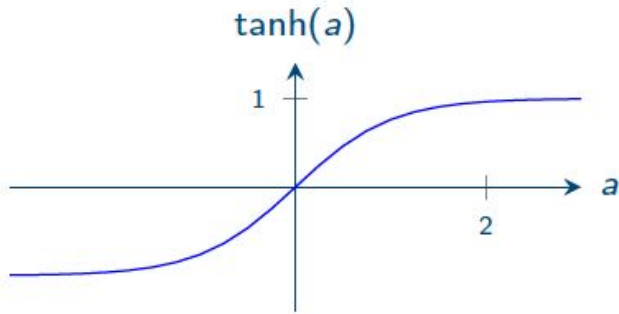
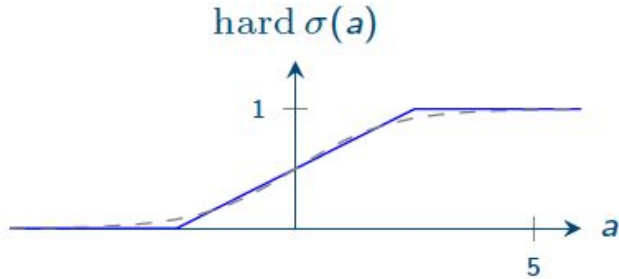
Why do we need non-linearities ?

If we only use linear layers we are only able to learn linear transformations of our input.



Single neuron model: Regression

Other popular activation functions:

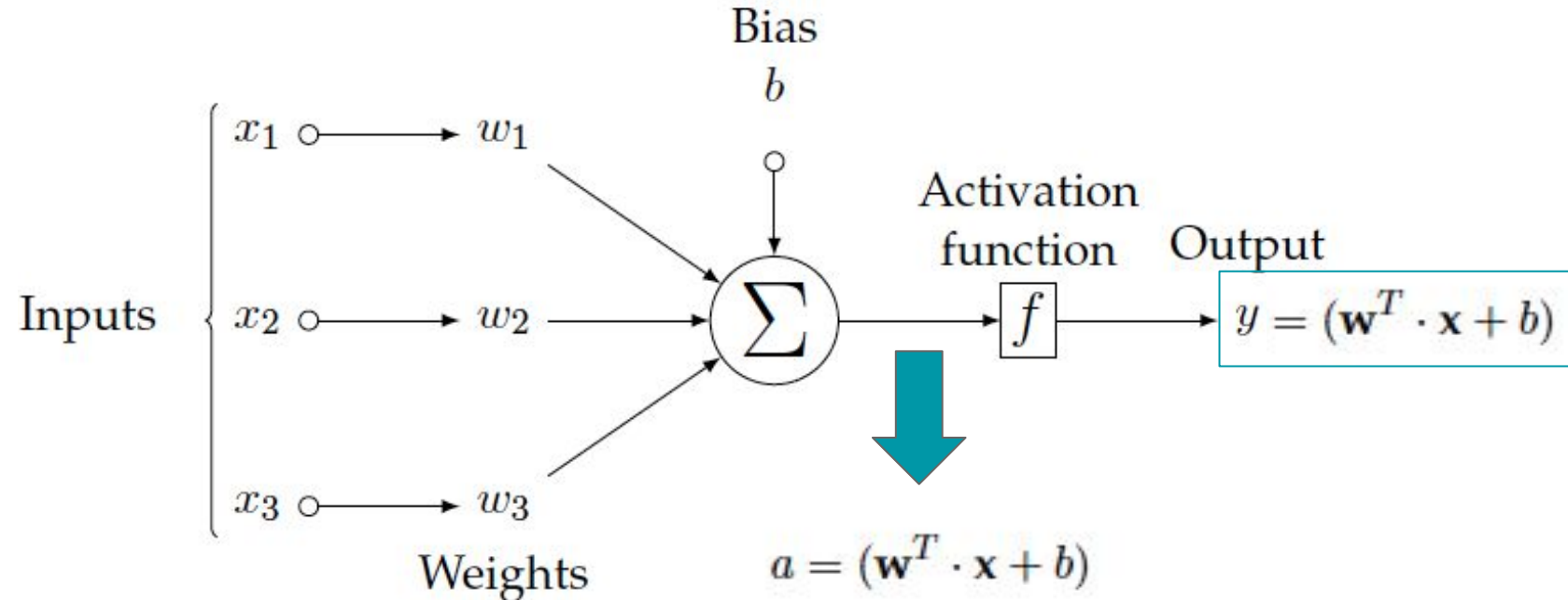


Outline

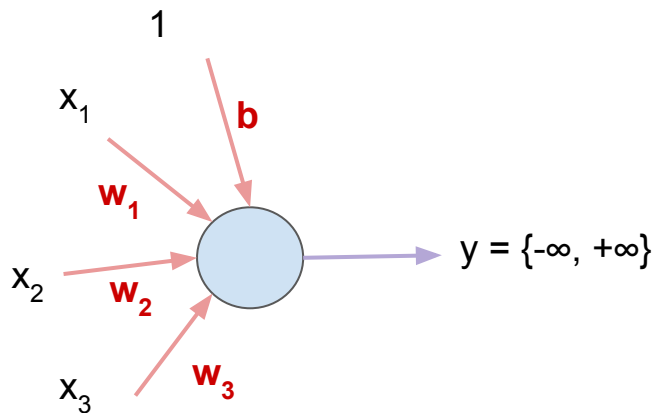
1. Single neuron model (Perceptron)
2. **Regression**
 - a. **Linear regression**
 - b. Logistic regression

Single neuron model: Linear Regression

A single neuron scheme can solve linear regression problems when $f(a)=a$.
[identity]



Single neuron model: Linear Regression



PYTORCH

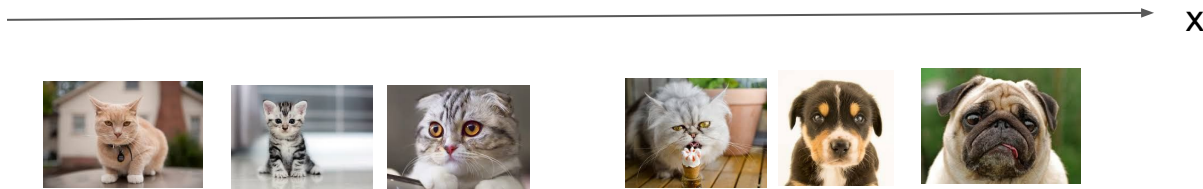
```
lir = nn.Sequential(  
    nn.Linear(NUM_INPUTS, 1)  
)
```

Outline

1. Single neuron model (Perceptron)
2. **Regression**
 - a. Linear regression
 - b. Logistic regression**
3. Limitations of the perceptron

Single neuron model: Binary Classification

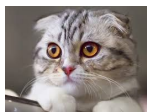
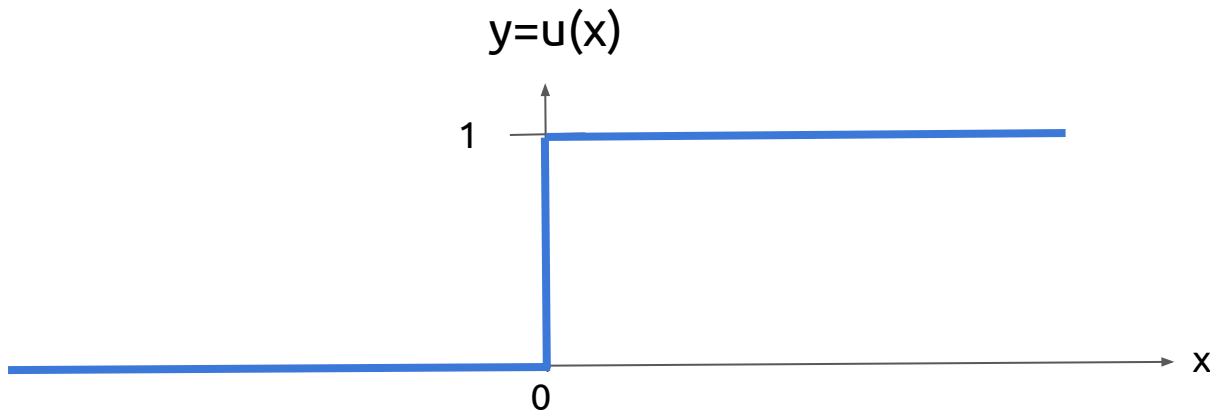
Question: Consider a problem of binary classification between cats (class 0) and dogs (class 1). How can a linear regressor be modified to provide 0 or 1 outputs ?



Single neuron model: Binary Classification

Question: Consider a problem of binary classification between cats (class 0) and dogs (class 1). How can a linear regressor be modified to provide 0 or 1 outputs ?

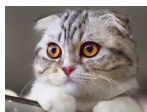
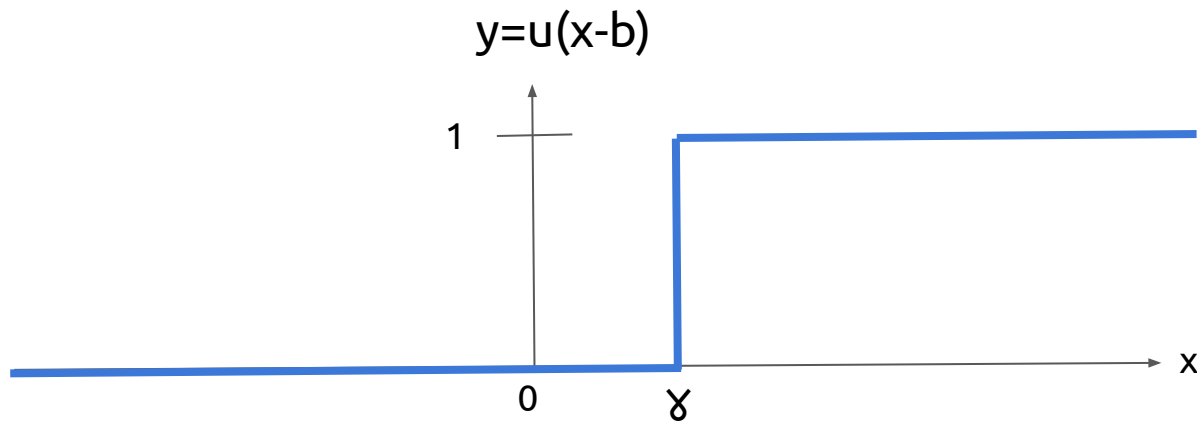
The heaviside (or step) function would generate 0 or 1 outputs only....



Single neuron model: Binary Classification

Question: Consider a problem of binary classification between dogs (class 0) and cats (class 1). How can a linear regressor be modified to provide 0 or 1 outputs ?

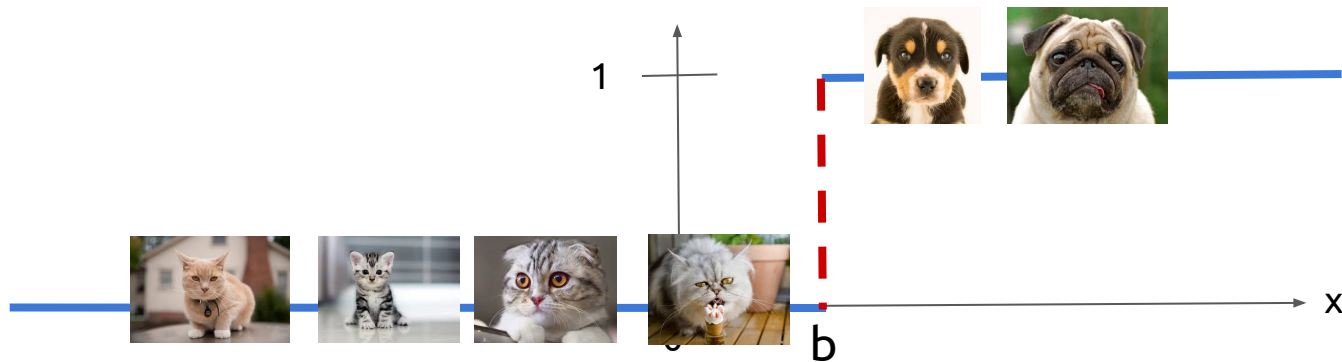
...the decision boundary could be easily set with a simple translation (b)...



Single neuron model: Binary Classification

Question: Consider a problem of binary classification between dogs (class 0) and cats (class 1). How can a linear regressor be modified to provide 0 or 1 outputs ?

The heaviside (or step) function would generate 0 or 1 outputs....



...but heaviside is unsuitable for deep learning because it is not differentiable (see later the “Backpropagation” lecture).

Single neuron model: Binary Classification

Question: Consider a problem of binary classification between dogs (class 0) and cats (class 1). How can a linear regressor be modified to provide 0 or 1 outputs ?

A differentiable solution approximation the heaviside function is the **sigmoid function** $\sigma(x)$, also referred as **logistic curve**.

$$\sigma(x) = \frac{1}{1 + e^{-x}}$$

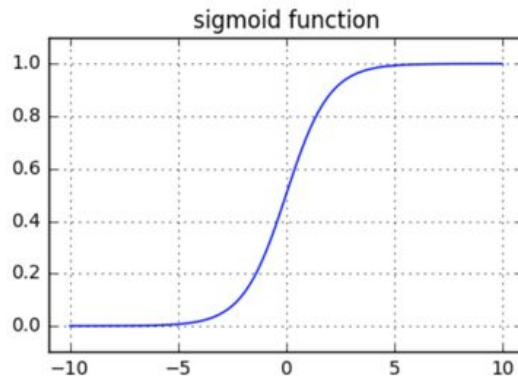
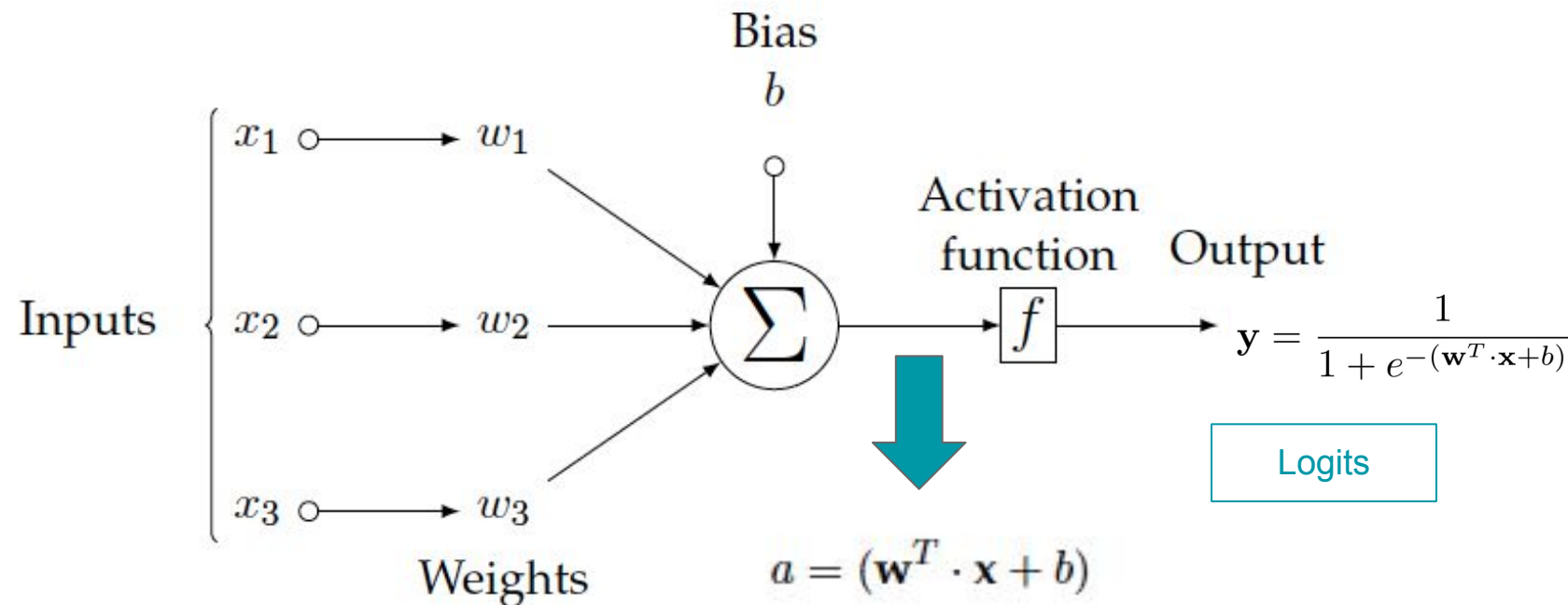


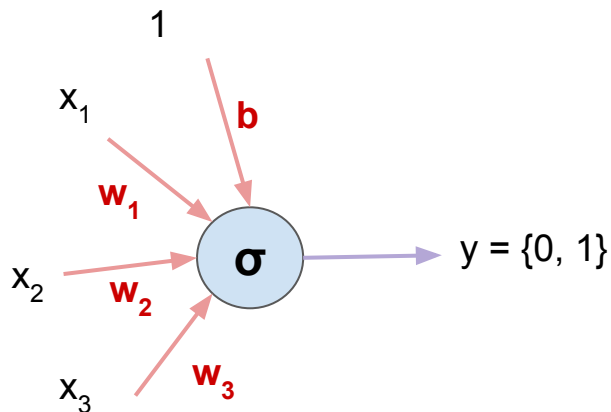
Figure: [Andrei Karpathy](#)

Single neuron model: Logistic Regression

The perceptron is suitable for classification problems when $f(a)=\sigma(a)$. [sigmoid]



Single neuron model: Logistic Regression

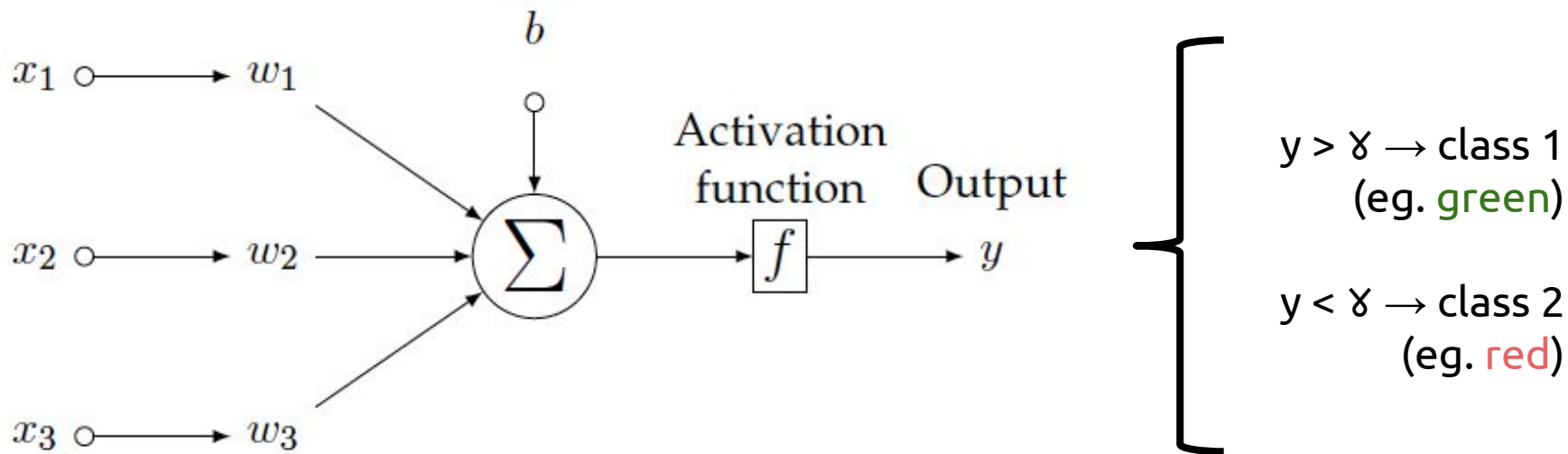


PYTORCH

```
lor = nn.Sequential(  
    nn.Linear(NUM_INPUTS, 1),  
    nn.Sigmoid()  
)
```

Single neuron model: Binary Classification

Setting a **threshold** at the output of the perceptron allows solving classification problems between two classes (binary):

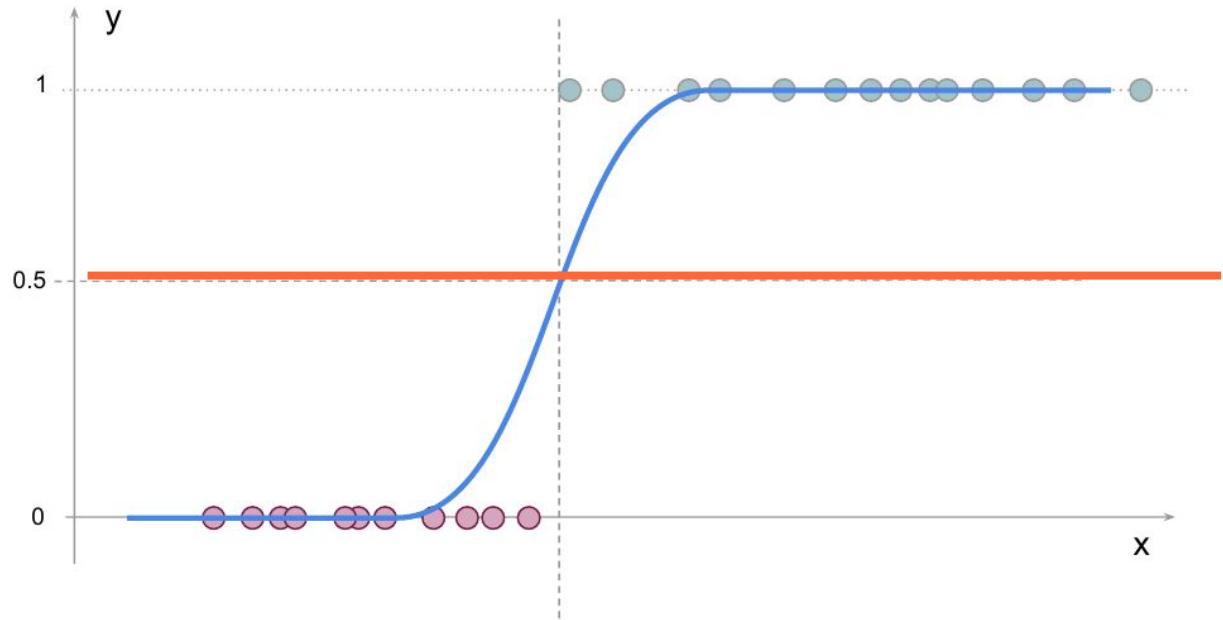


Single neuron model: Binary Classification

For classification, regressed values should be collapsed into 0 and 1 to quantize the confidence of the predictions ("probabilities").

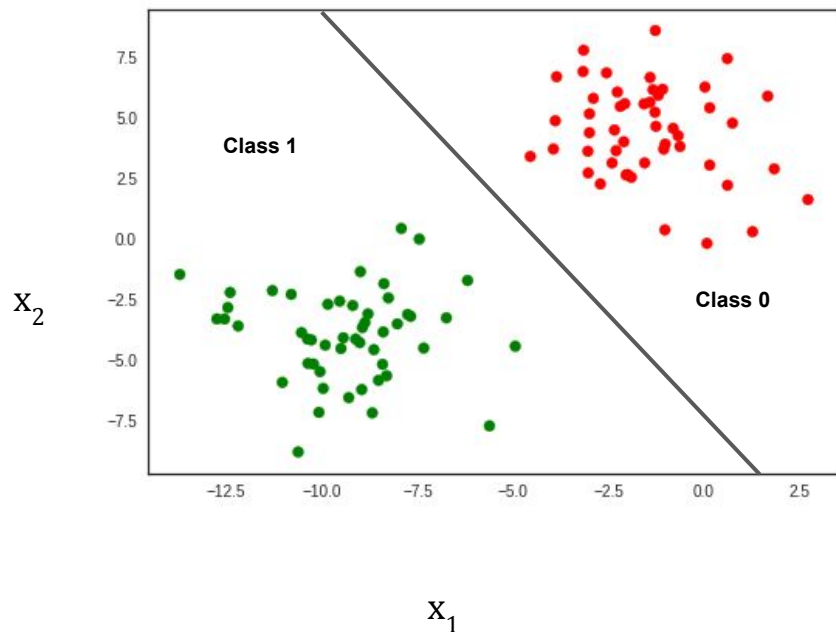
$$\sigma(\mathbf{x}) = \frac{1}{1 + e^{-(\mathbf{w}^T \cdot \mathbf{x} + b)}}$$

Threshold (γ)



Single neuron model: Binary Classification

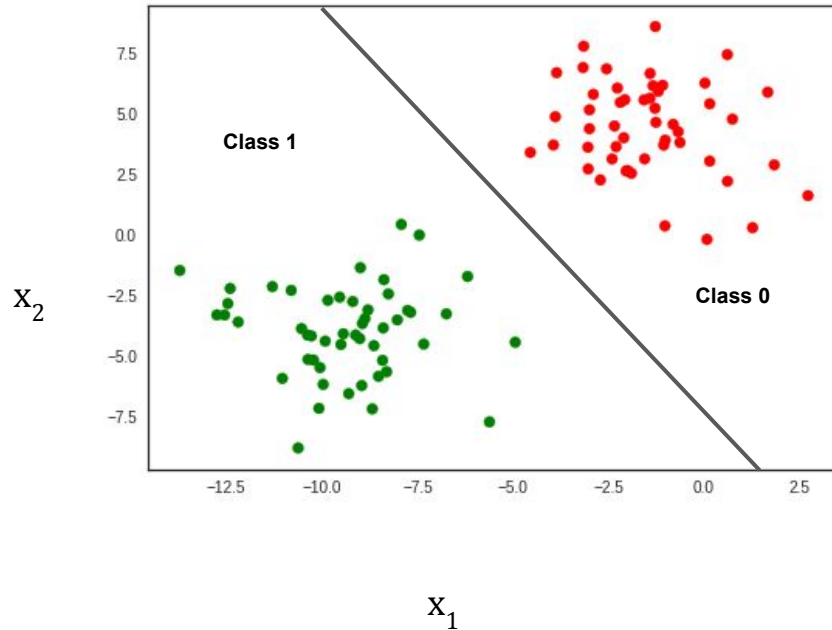
2D input space data



$$f(x) = \begin{cases} 1 & \text{if } w \cdot x + b > 0.5 \\ 0 & \text{otherwise} \end{cases}$$

Single neuron model: Binary Classification

2D input space data



Parameters of the line.

They are estimated based on training data - *Learning Stage*.

$$f(x) = \begin{cases} 1 & \text{if } w \cdot x + b > 0.5 \\ 0 & \text{otherwise} \end{cases}$$

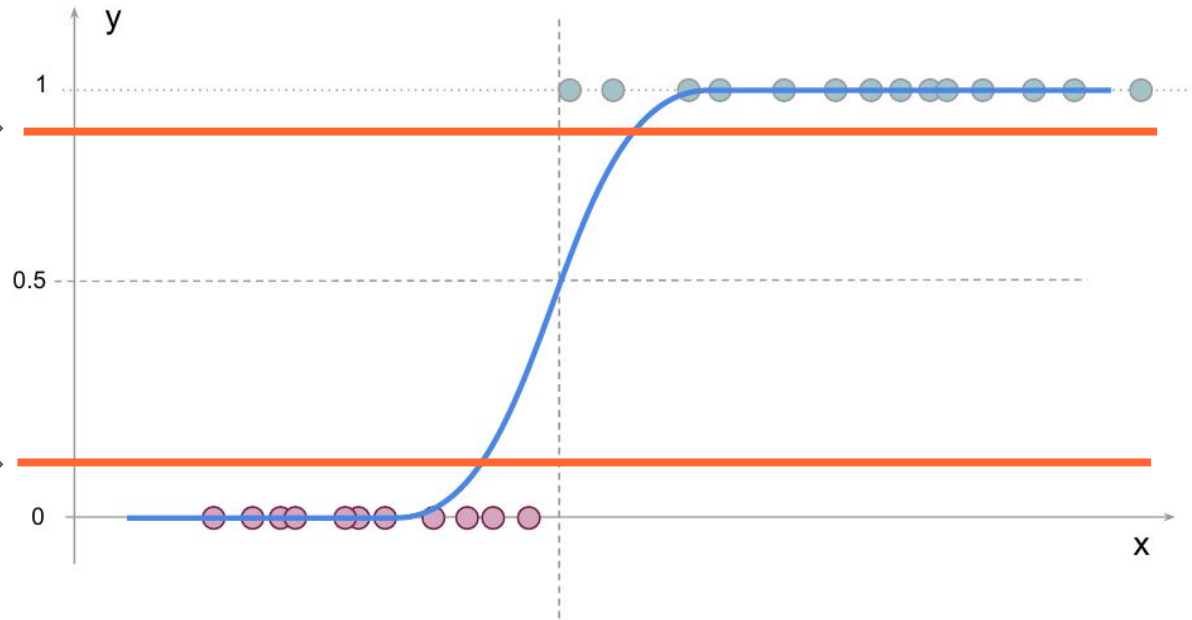
The equation shows the decision function $f(x)$ based on the weighted sum of inputs $w \cdot x + b$. The parameters w and b are circled in the original image, with lines pointing to the text 'Parameters of the line. They are estimated based on training data - Learning Stage.'

Single neuron model: Binary Classification

The classification threshold can be adjusted based on the desired precision - recall trade-off:

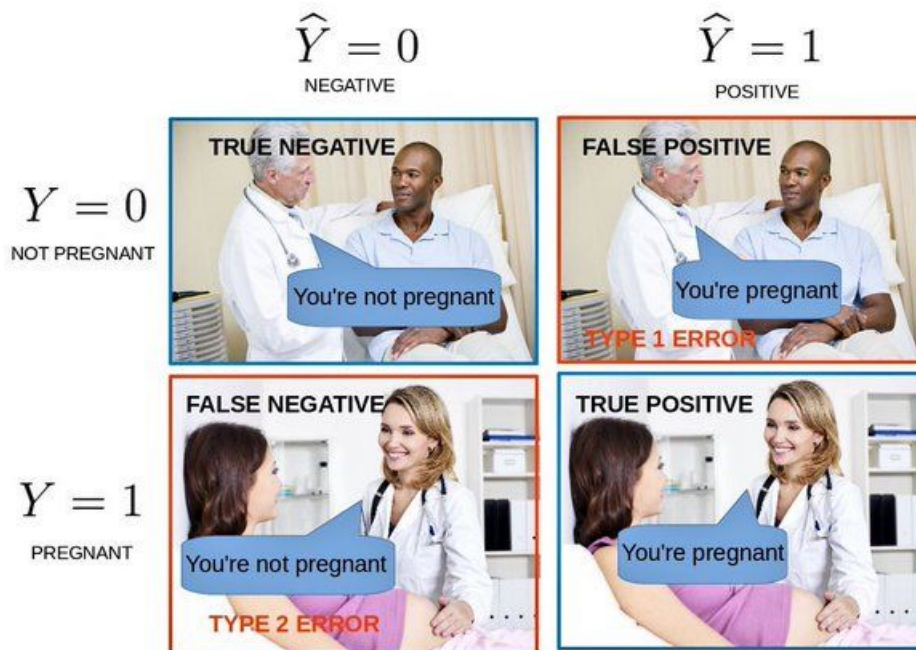
High precision & low recall for class green

Low precision & high recall for class green



Single neuron model: Binary Classification

Adjusting the decision threshold allows defining whether false positives or false negatives are more critical for our application.



Single neuron model: Binary Classification

Exercise: Consider a binary classifier implemented with a single neuron modelled by two weights $w_1=0.2$ and $w_2=0.8$ and a bias $b=-1$. Consider the activation function to be a sigmoid $f(x) = 1 / (1+e^{-x})$.

- a) Draw a scheme of the model.
- b) Compute the output of the logistic regressor for a given input $x=[1,1]$.
- c) Considering a classification threshold of $y_{th}=0.9$ ($y_{th} > 0.9$ for class A, and $y_{th} < 0.9$ for class B), which class would be predicted for the considered input $x=[1,1]$?

Outline

1. Single neuron model (Perceptron)
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Learn more

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A STORY LIVES FOREVER



The video player shows Marvin Minsky, a man with glasses, speaking and gesturing with his hands. He is surrounded by several green dinosaur puppets. The video player interface includes a progress bar at 00:06 / 02:07, a volume icon, and a full screen icon. On the right side of the player, there are three icons: a share icon, a full screen icon, and a link icon. Below the video player, the title "The problem with perceptrons" is displayed in blue, followed by the subtitle "Marvin Minsky Scientist". To the right of the title is a heart icon, and to the right of the heart is a blue button labeled "Play all".

The problem with perceptrons
Marvin Minsky Scientist

Play all

Minsky, Marvin, and Seymour A. Papert. [Perceptrons: An introduction to computational geometry](#). 1969

Undergradese

What undergrads ask vs. what they're REALLY asking

"Is it going to be an open book exam?"

Translation: "I don't have to actually memorize anything, do I?"

"Hmm, what do you mean by that?"

Translation: "What's the answer so we can all go home."

"Are you going to have office hours today?"

Translation: "Can I do my homework in your office?"

"Can i get an extension?"

Translation: "Can you re-arrange your life around mine?"

"Is this going to be on the test?"

Translation: "Tell us what's going to be on the test."

"Is grading going to be curved?"

Translation: "Can I do a mediocre job and still get an A?"

