3 October, 2017

Neural Networks

Course 1

Overview

- Course Evaluation
- What is a neural network?!
- Neuron types
- History of neural networks
- Artificial Network evaluation?

Course Evaluation

Evaluation

<u>Course Requirements</u>

- 40% of the final grade
- Points will be received from a final test that will take place during the examination session

Minimum 35 points of 100

<u>Laboratory Requirements</u>

- 60% of the final grade
- Points can be received by completing 3 assignments and a project

Minimum 35 points of 100

Evaluation

<u>More about the Laboratory</u>:

100 points divided in 4 assignments:

- First Half of the semester:
  - Assignment 1: 10 points
  - Assignment 2: 15 points
  - Assignment 3: 25 points

- Second Half of the semester
  - Project: maximum 50 points

Evaluation

More about the Laboratory:

During the first half of the semester:

Each group of students will be divided in two:

- First Semigroup: last name begins with a letter $\in [A, M]$
- Second Semigroup: last name begins with a letter $\in [N, Z]$

Each semigroup will come to the laboratory once every two weeks (except the first week which is common)

During the second half of the semester:

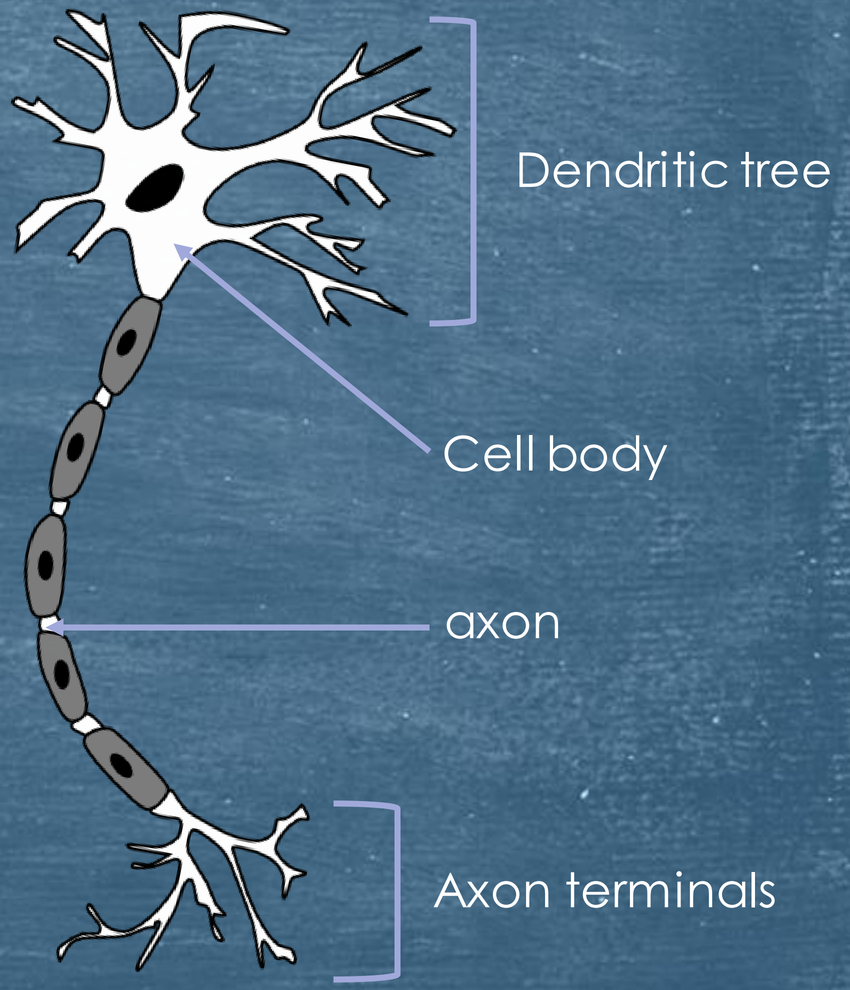
The project will be completed by a group of two students

What is a neural network

What is a neural network?

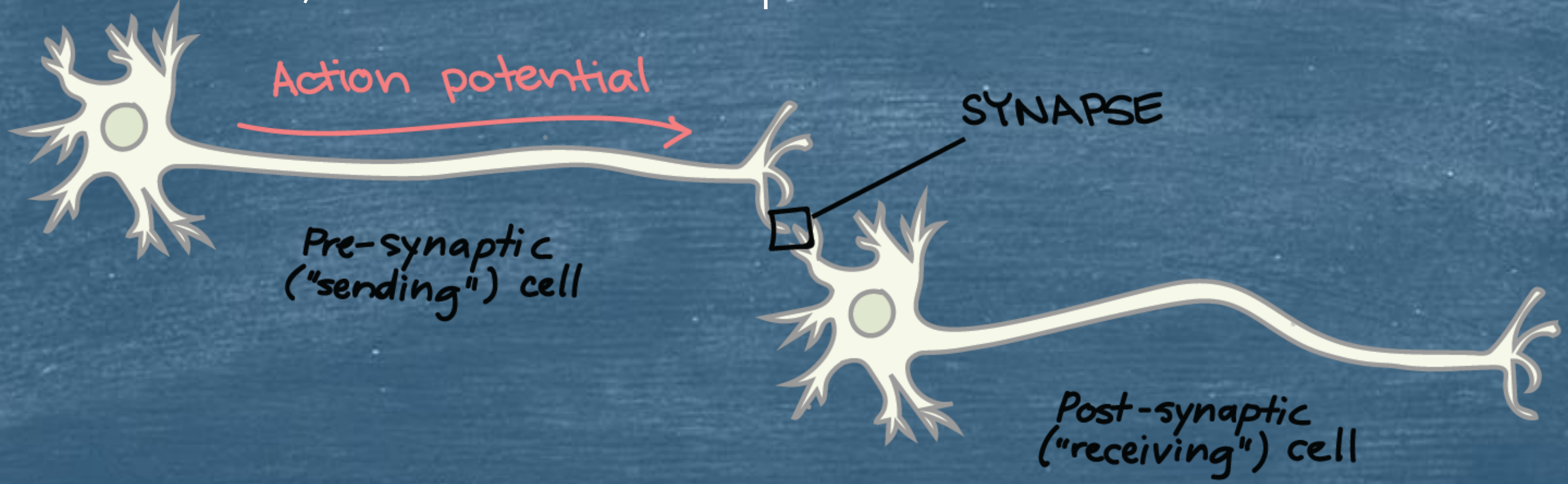
What is a neuron?

- The building block of the nervous system
- Specialized in transmitting information
- 3 important parts:
  - Axon and axon terminals
  - Dendrites
  - Cell body



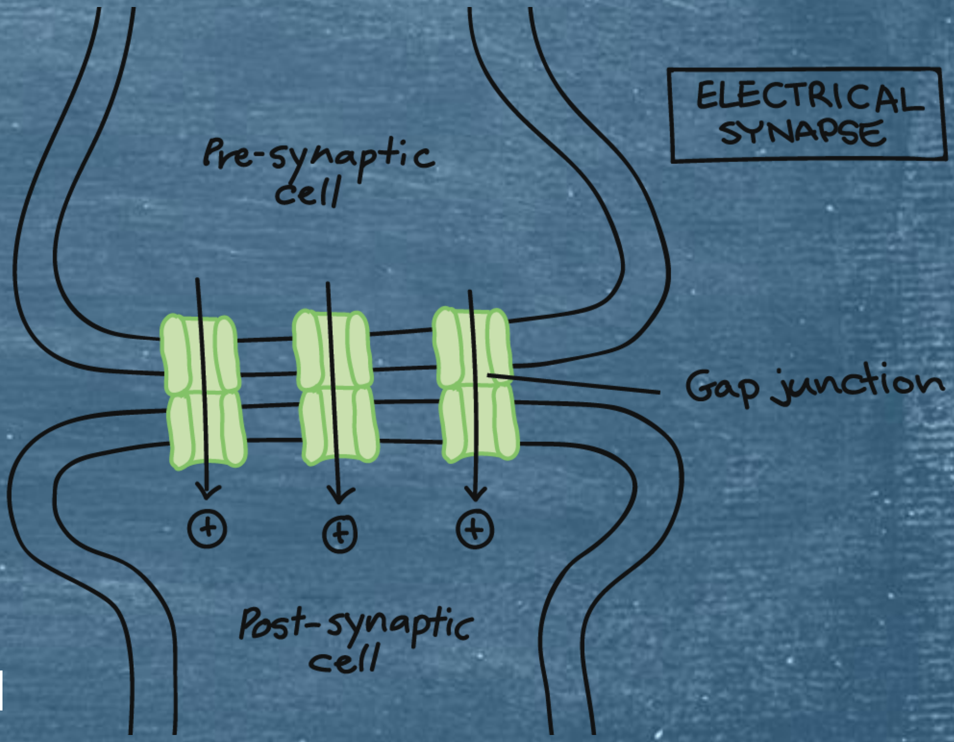
What is a neural network?

- Each neuron receives information through its dentritic tree
- Each neuron transmites information through the axon
- A neuron fires when it receives enough information from neurons connected to the dentritic tree. (Enough is determined in the cell body)
- If a neuron fires, it will fire at its full potential



What is a neural network?

- Synapse = the place where two neurons meet
- The information is transmitted through vesicles situated at the end of axon
- There are different kinds of transmitters:
  - Positive signals
  - Negative signals
- If a neuron fires, it will fire at its full potential



What is a neural network?

- Synapses can adapt:
  - By varying the number of transmitted vesicles
  - By varying the number of receptor molecules

  How do they adapt?

- The brain has about 100 billion (10^{11}) nerve cells each that can have 1000 (10^4) connections

- Each cell fires in certain cases (for example, when you see an edge, a color, or when you see a combinations of these detected by other neurons)

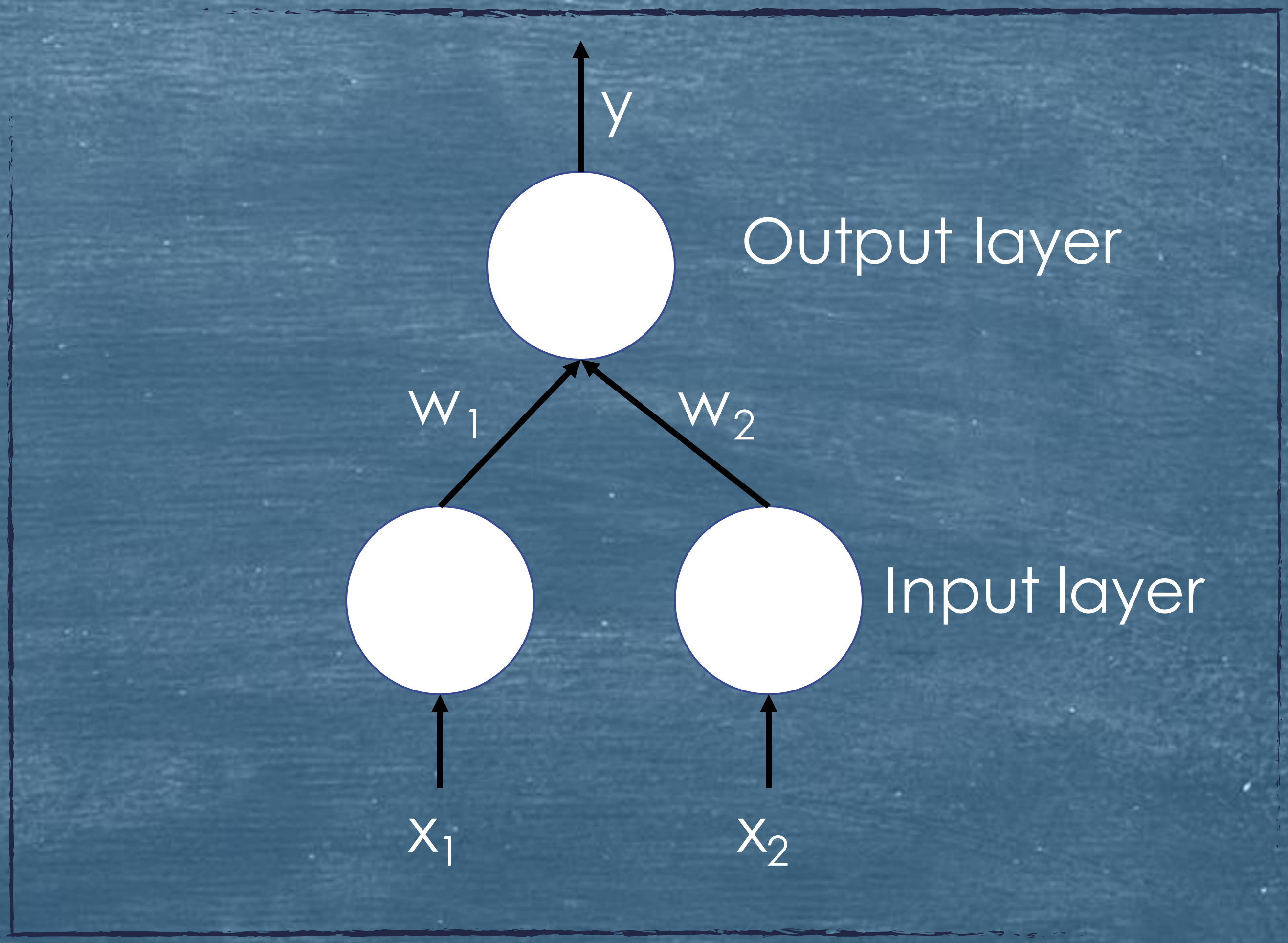
What is a neural network?

Brief:

Neurons use spikes to communicate

The effect of each connection is controlled by a synaptic weight

The synaptic weights adapt so the whole network behaves properly



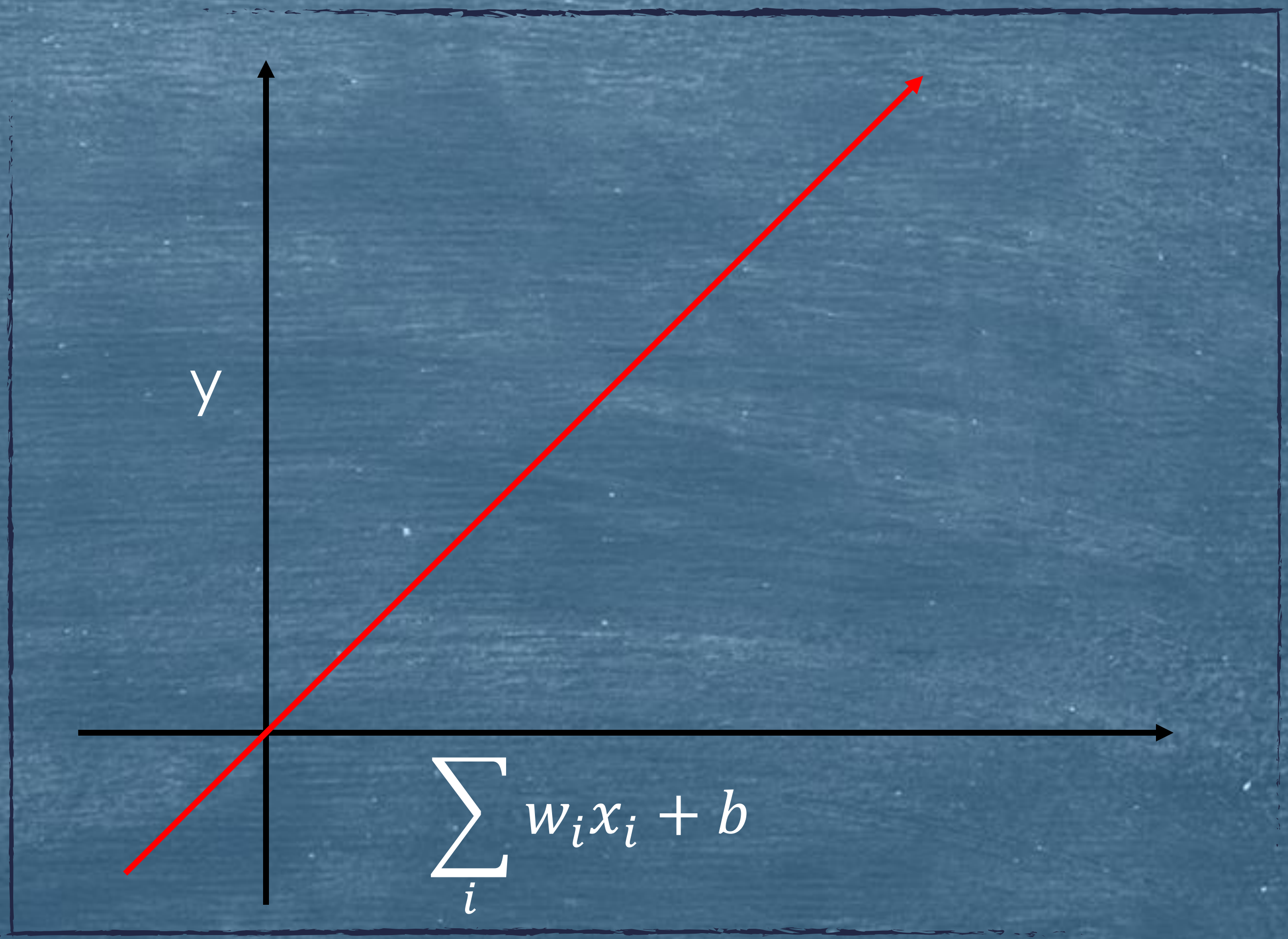
Types of Neurons

Types of neurons

Linear neurons:

The output is a weighted sum of the input + a bias

$$y = \sum_i w_i x_i + b$$



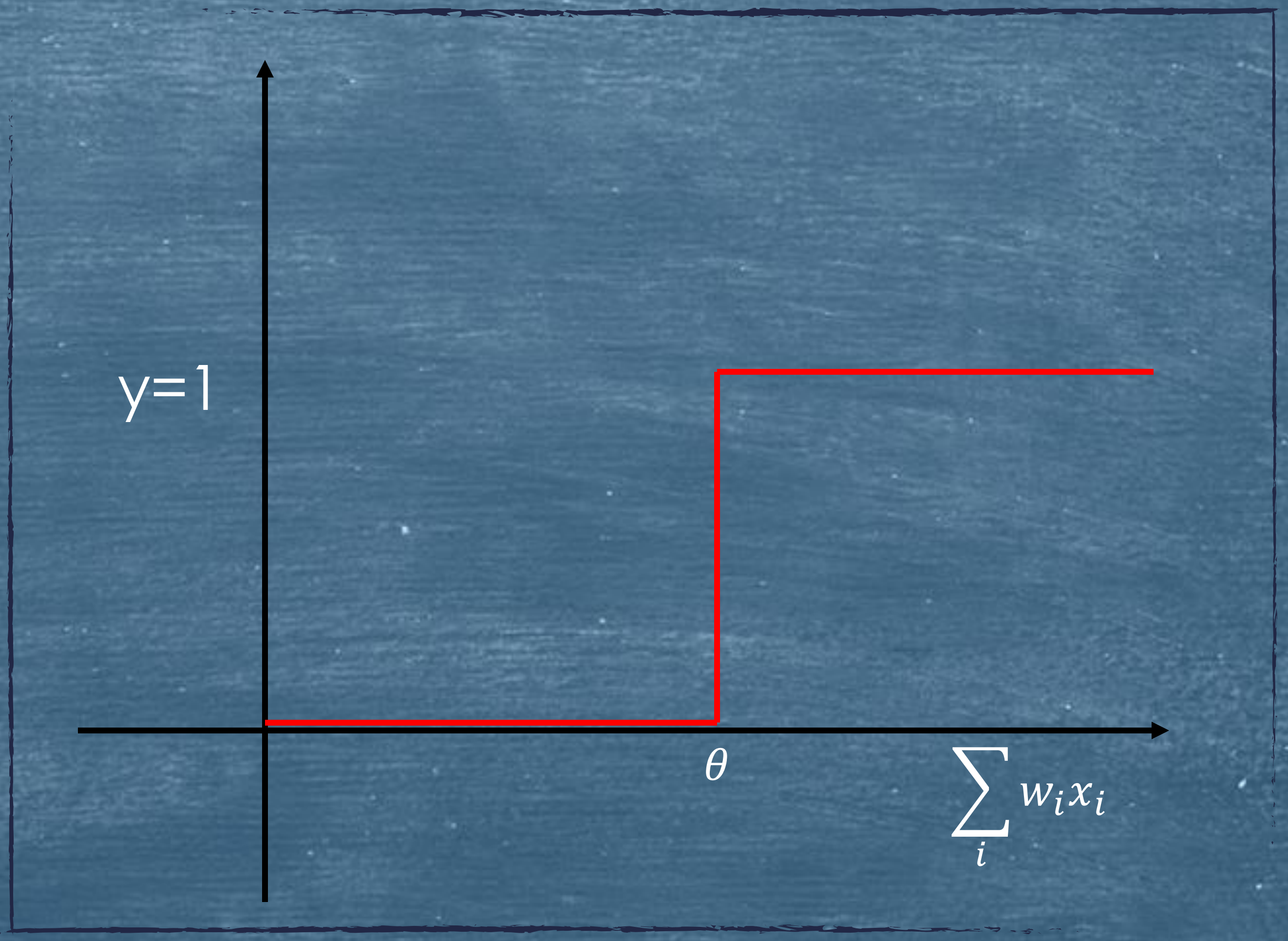
Types of neurons

Binary Threshold:

Compute the weighted sum of the input

If above a threshold, output1, else output 0

$$y= \begin{cases} 1, if \ \sum_{i=0}^{n} x_i w_i \geq \theta \\ 0, otherwise \end{cases}$$



Types of neurons

Binary Threshold:

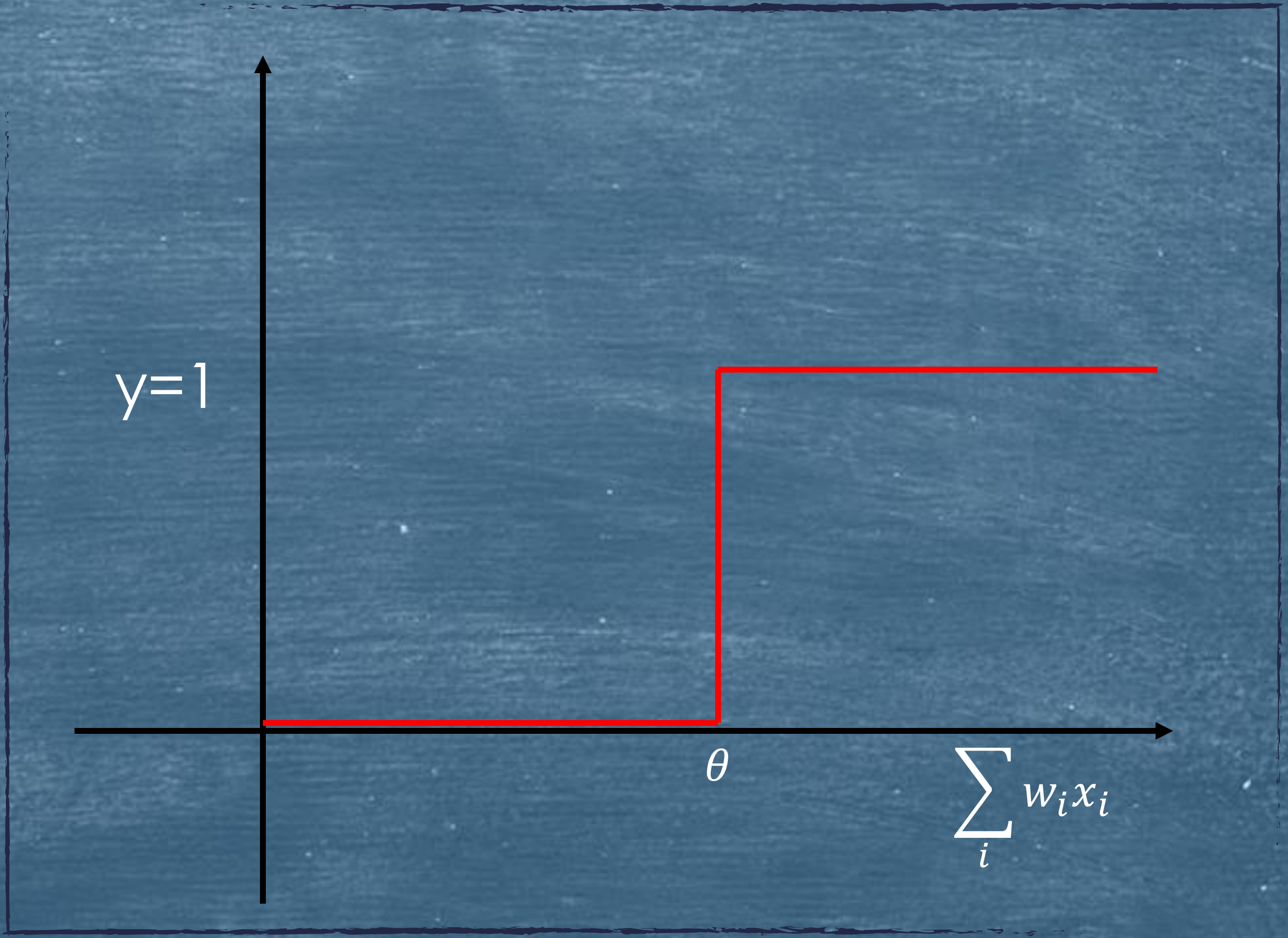
Compute the weighted sum of the input

If above a threshold, output1, else output 0

y= $\begin{cases} 1, if \ \sum_{i=0}^{n} x_i w_i \geq \theta \\ 0, otherwise \end{cases}$

$\theta = -b$, then

y= $\begin{cases} 1, if \ \sum_{i=0}^{n} x_i w_i + b \geq 0 \\ 0, otherwise \end{cases}$



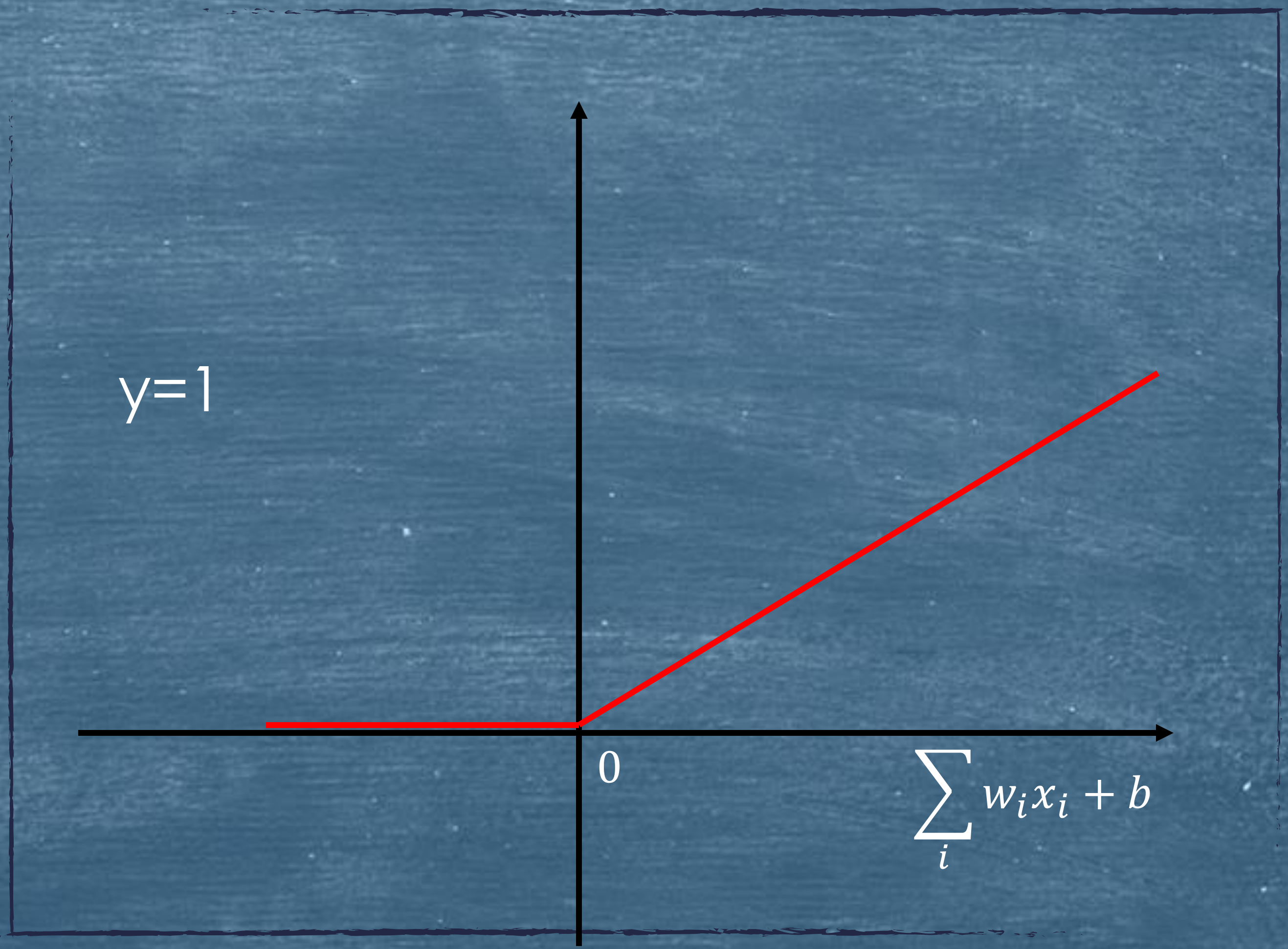
Types of neurons

Rectified Linear Unit:

Combines a linear neuron and a binary threshold unit

$$z = \sum_i w_i x_i + b$$

$$y = \begin{cases} z \; if \; z \geq 0 \\ 0, otherwise \end{cases}$$



Types of neurons

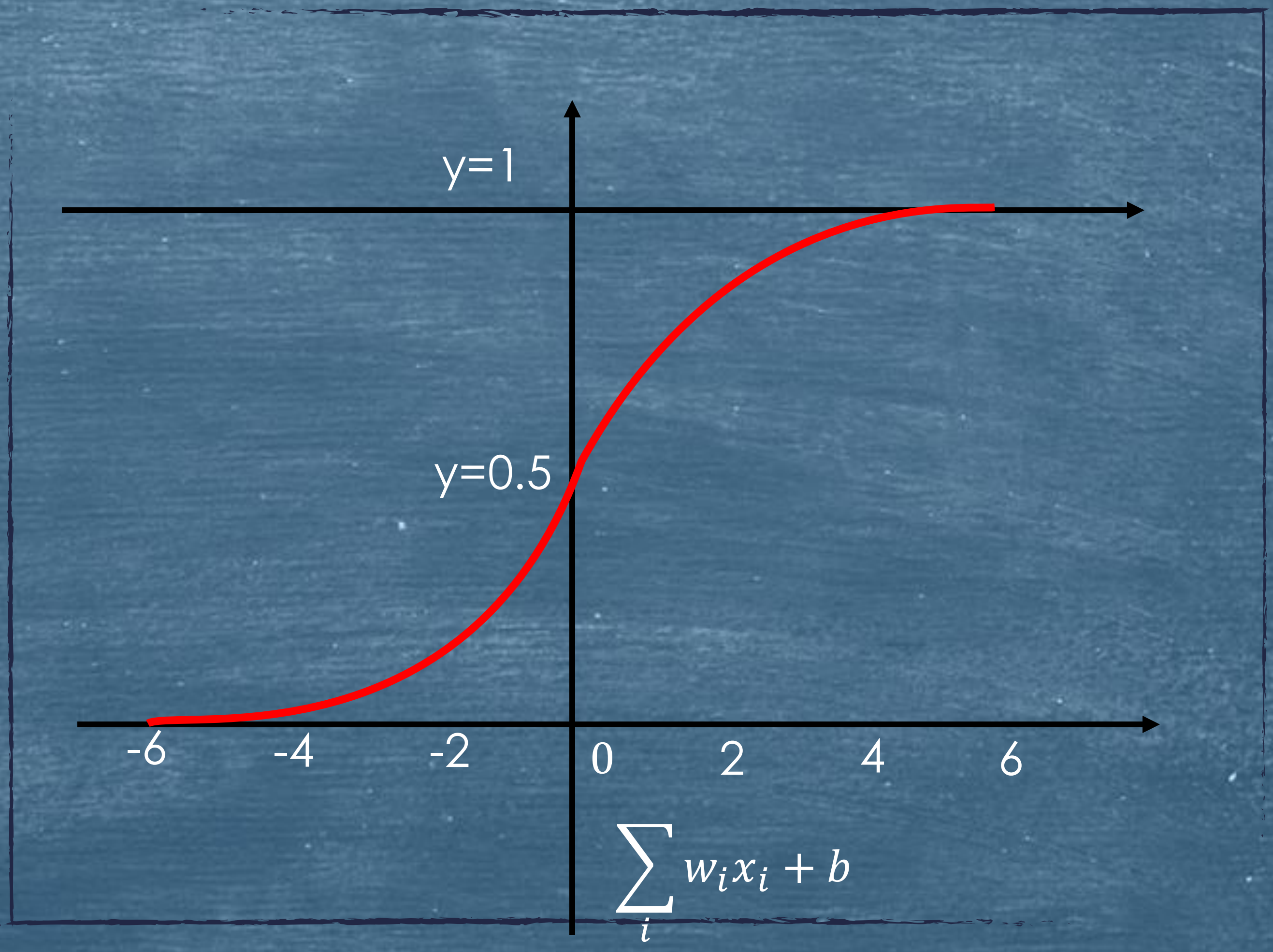
Logistic neurons:

The most used in neural networks

1. Compute the weighted sum of the input
2. Apply the logistic function

$$z = \sum_i w_i x_i + b$$

$$y = \frac{1}{1 + e^{-z}}$$



Types of neurons

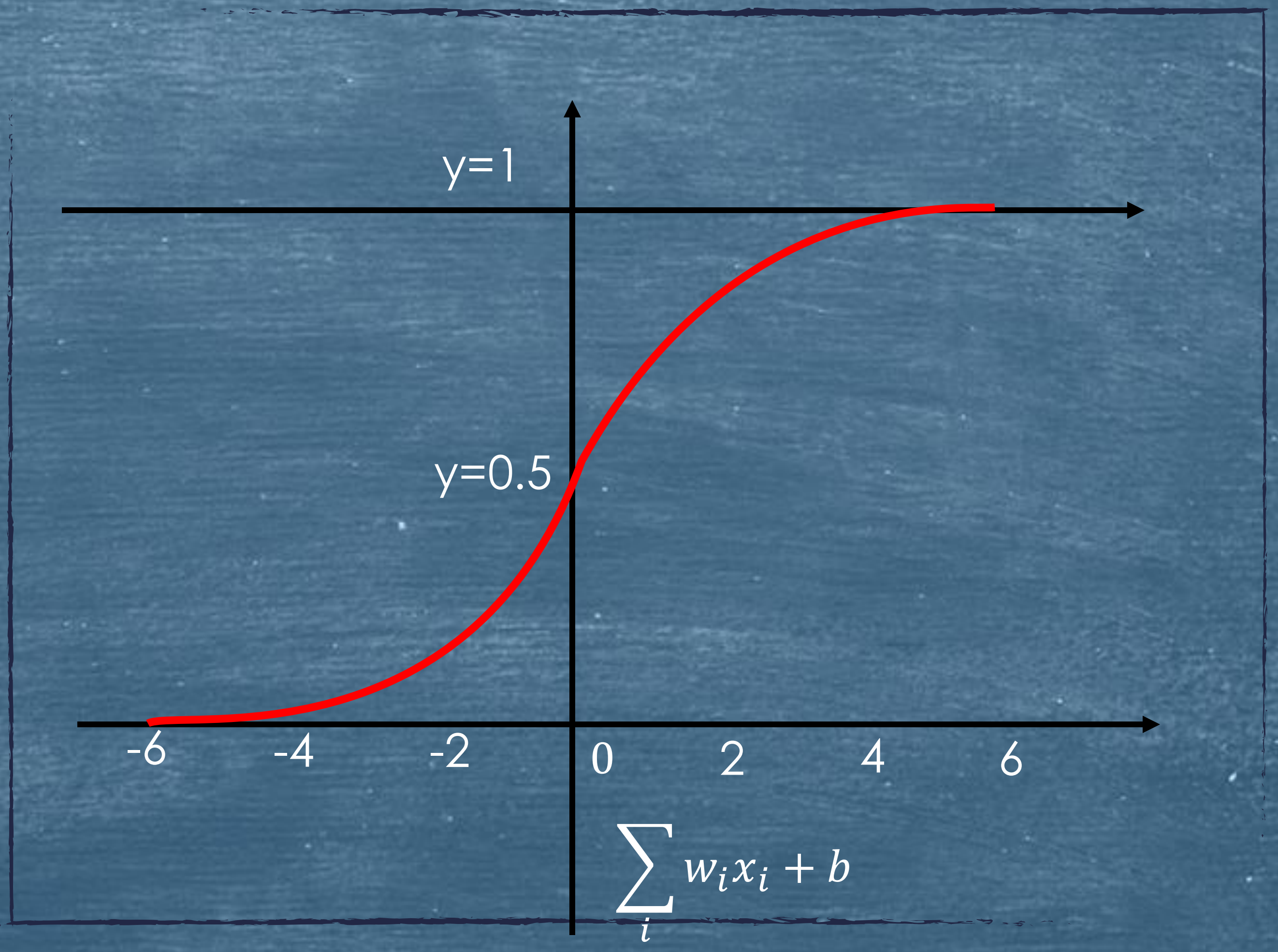
Stochastic binary neurons:

1. Compute the same value as logistic neurons
2. Consider the value as a probability of generating the value 1

$$z = \sum_i w_i x_i + b$$

$$p = \frac{1}{1 + e^{-z}}$$

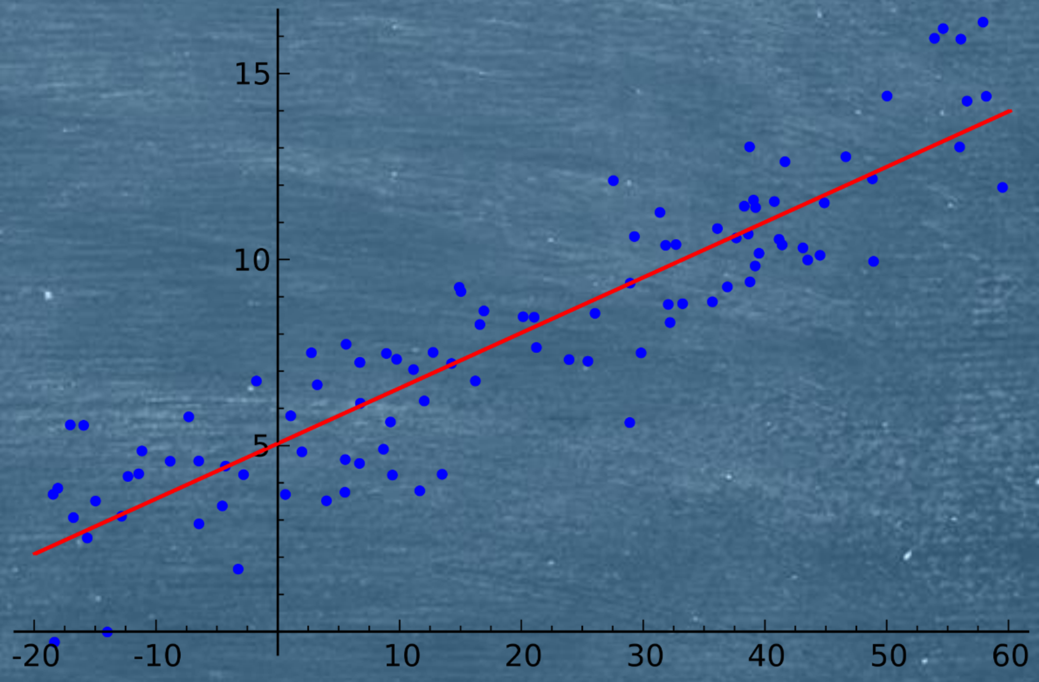
$$y = \begin{cases} 1, with\ prob(p) \\ 0, with\ prob(1 - p) \end{cases}$$



History of neural networks

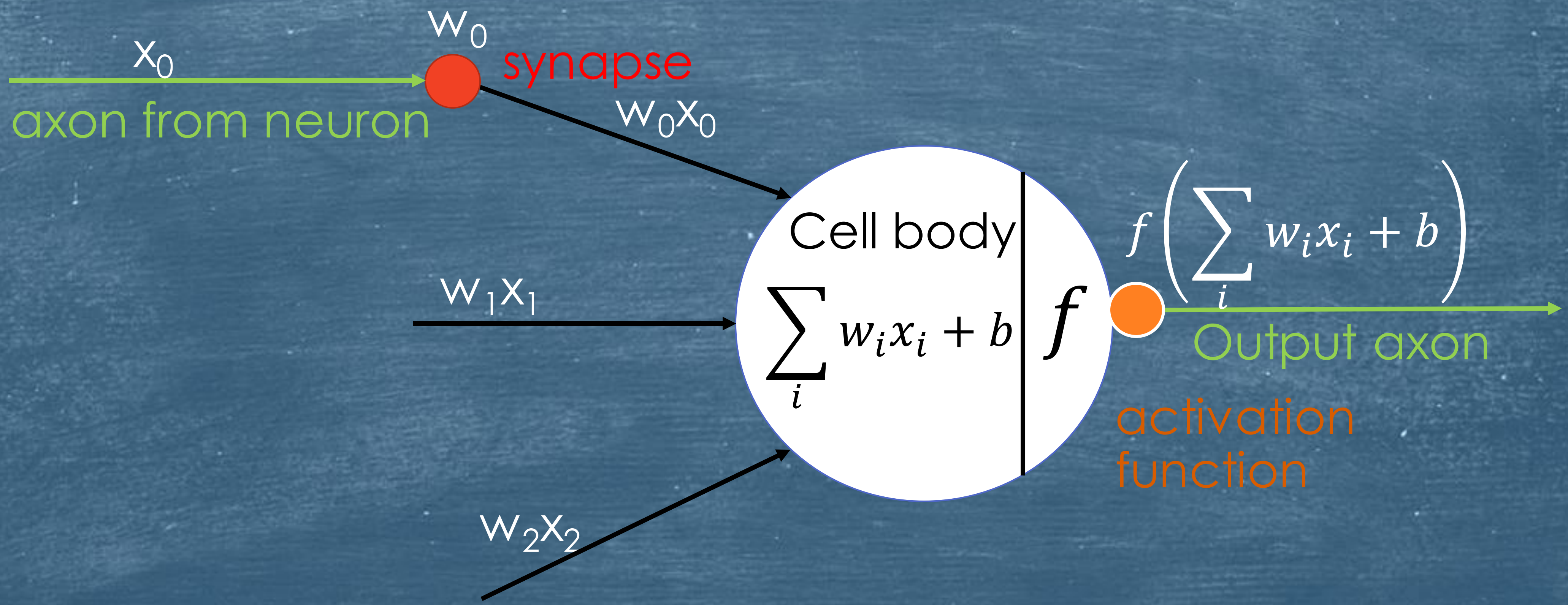
Neural Networks History

- Simple linear regression
  - Attempts to explain the relationship between two (x, y) or more variables using a straight line



Neural Networks History

- McCulloch-Pitts model (1943)



Neural Networks History

- The Perceptron model (1957) invented by Frank Rosenblatt
- Brought a learning method for the McCulloch-Pitts model, inspired by the work of neuropsychologist Donald Hebb
- The learning was very simple:
  - If the algorithm misclassifies an element, increase the weights if the output of the perceptron is too low compared to the example or decrease it if it is too high.
  - The activation function is very simple:

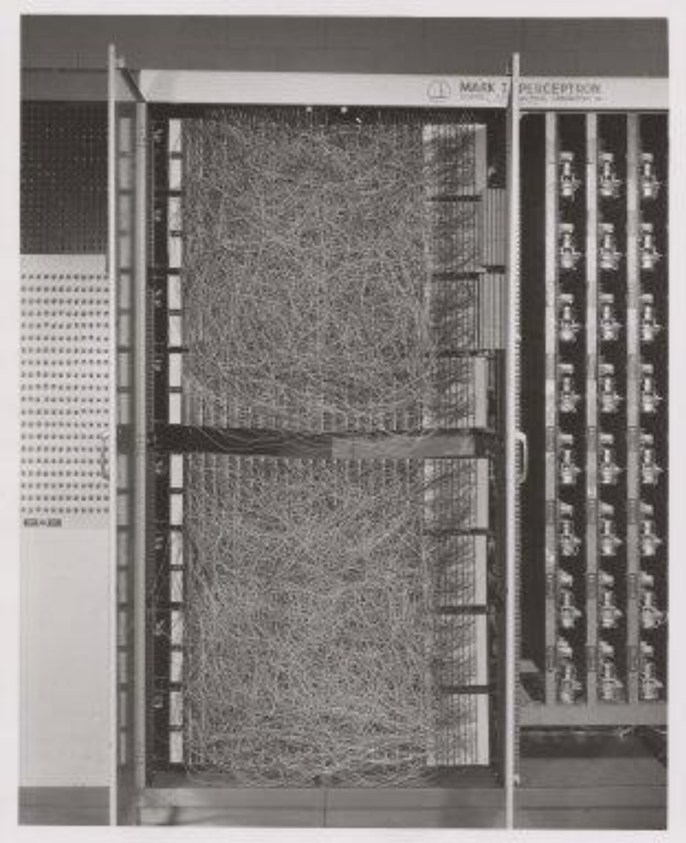
$$f = \begin{cases} 1, if \sum_{i=0}^{n} x_i w_i + b > 0 \\ 0, otherwise \end{cases}$$

Neural Networks History

- People started considering that perceptrons can do very complex tasks, like translation and image recognition
- Rosenblatt said in New York Times:

„*The Navy revealed the embryo of an electronic computer today that it expects will be able to walk, talk, see, write, reproduce itself an be conscious of its existence*”

Neural Networks History

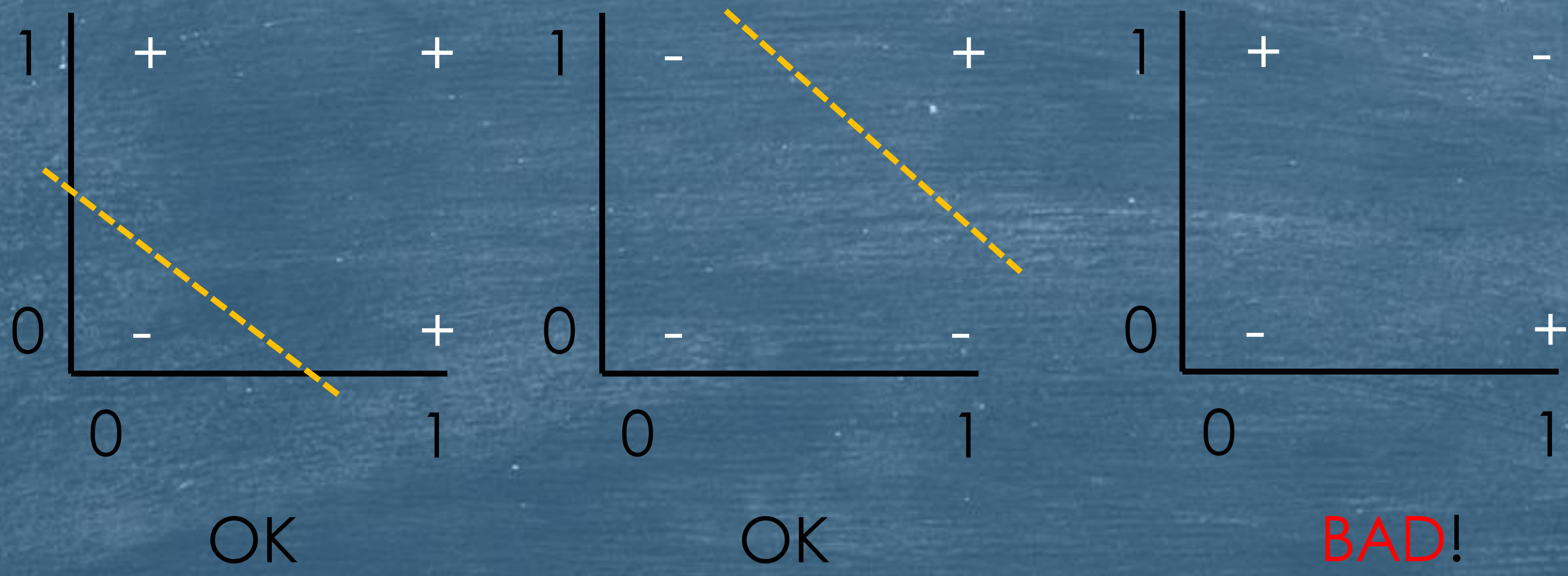


Mark1 Perceptron:

A system made of 400 perceptrons (20x20) was built to analyze images taken by planes during cold war

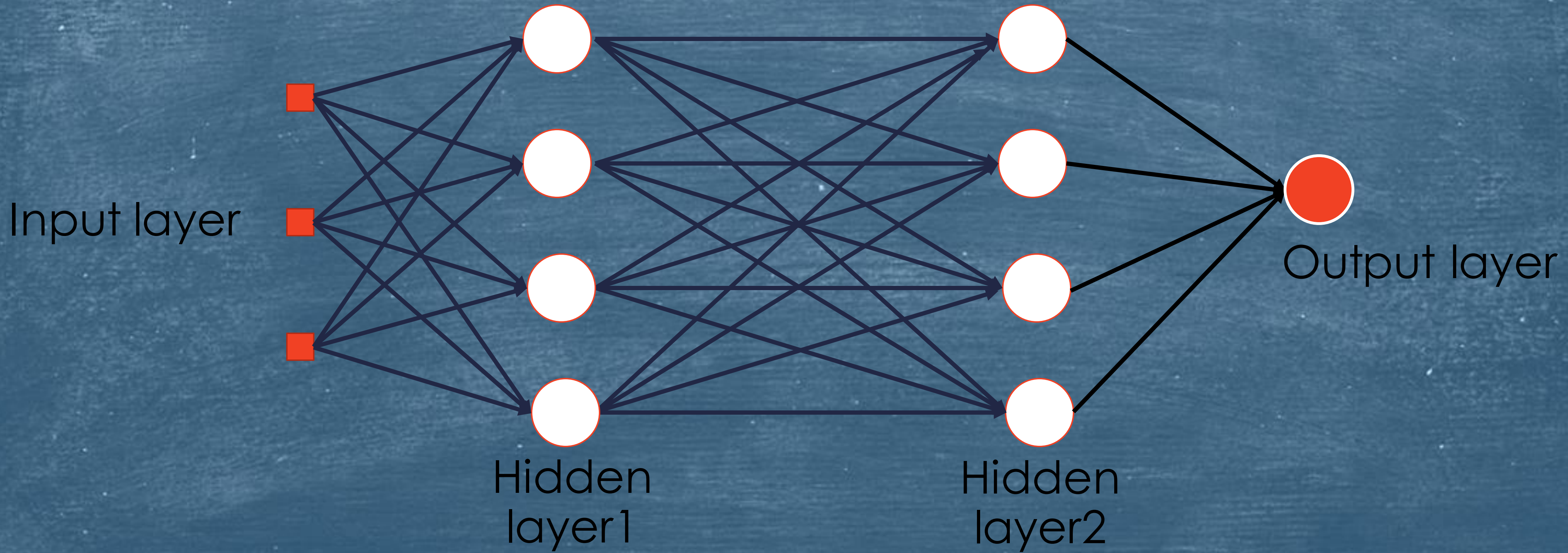
Neural Networks History

- First winter of Neural Networks:
  - Marvin Minsky and Seymour Papert publishes a book ("Perceptrons") in 1969 in which describes important problems of the perceptron
  - Most important problem: fails to compute the xor function



Neural Networks History

- Multilayer perceptrons:
  - Can not be trained with the simple perceptron rule since the error does not propagate beyond the last hidden layer

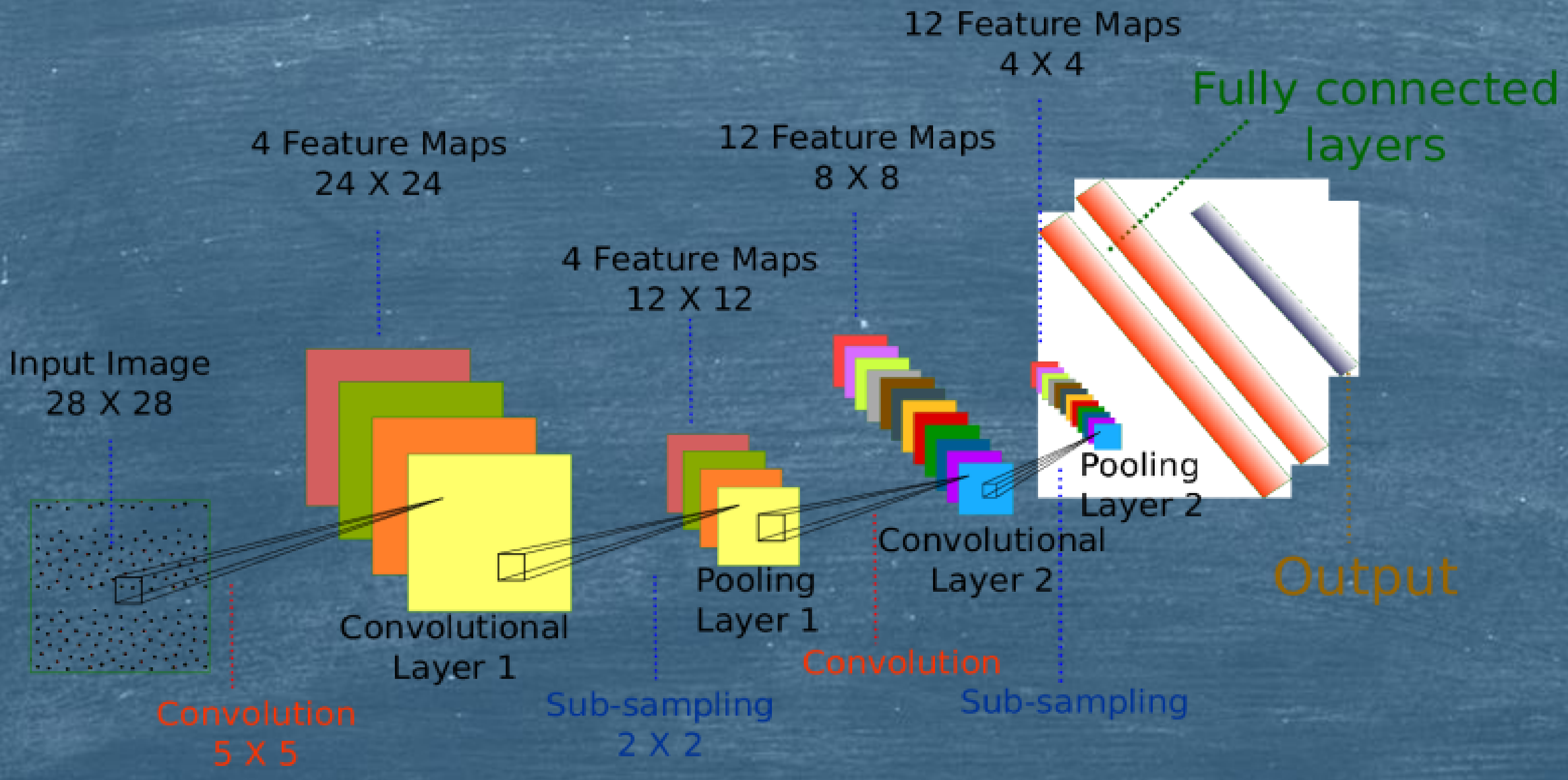


Neural Networks History

- Backpropagation algorithm
  - Proposed by Paul Werbos in his PhD thesis in 1974, but first published in 1982
  - The paper “Learning representations by back-propagating errors” by David Rumelhart, **Geoffrey Hinton** and Ronald Williams brought neural networks back to light
- The paper “Multilayer feedforward networks are universal approximators” (1989) proved that feed forward networks can theoretically implement any function (including XOR)

Neural Networks History

- 1989: LeNet (Convolutional neural network) created by Yann LeCun and collegues from AT&T Bell Labs

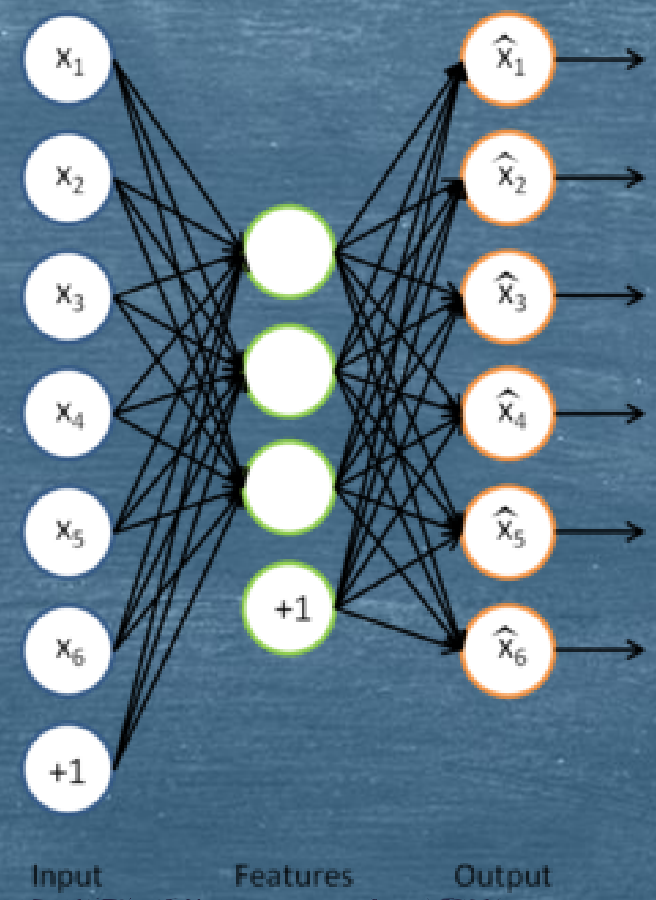


Neural Networks History

- Unsupervised Learning:

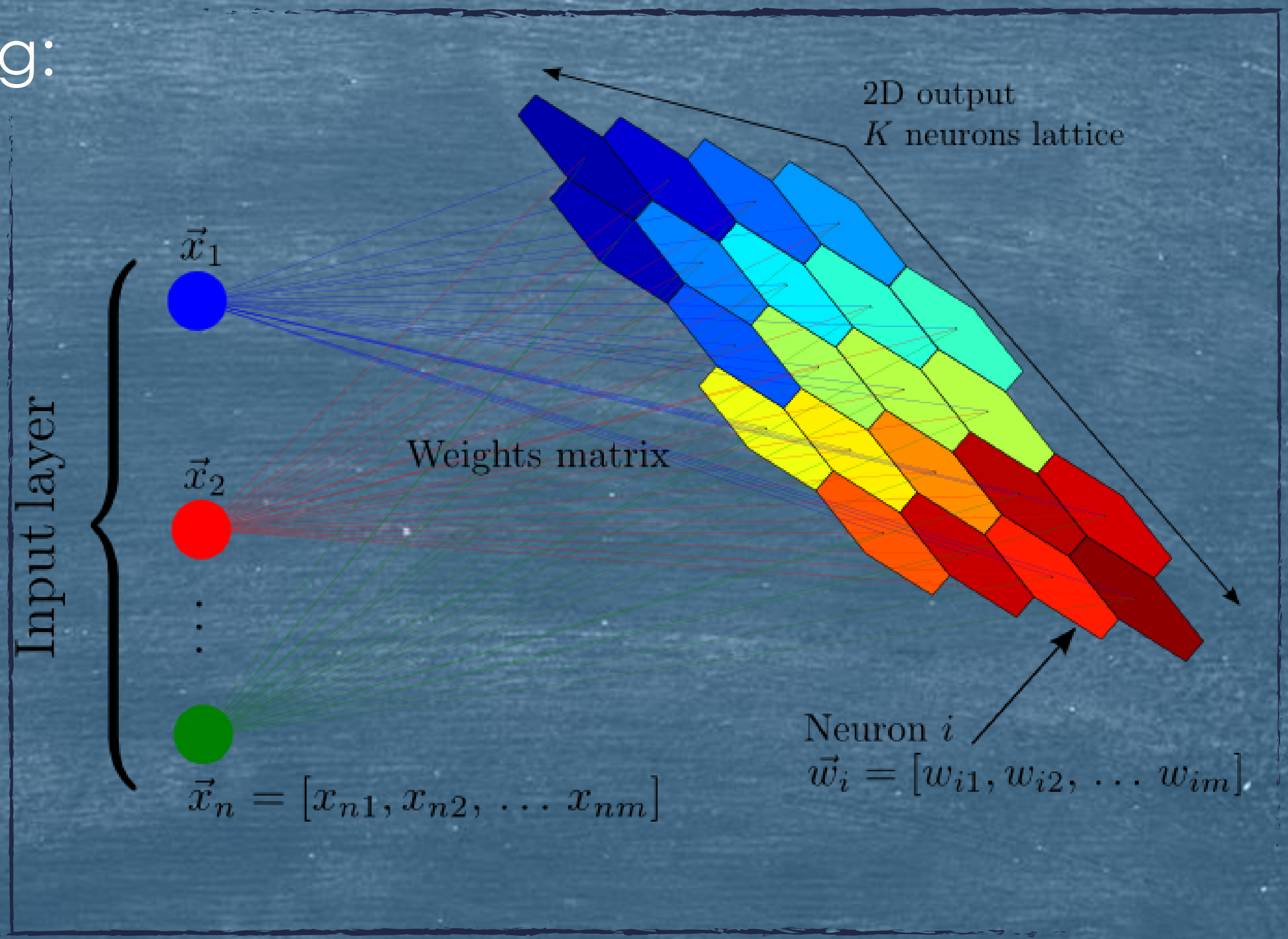
Autoencoders:

Achieving data compressions by relying on particularities of the data



Neural Networks History

- Unsupervised Learning:



Self Organising Maps:

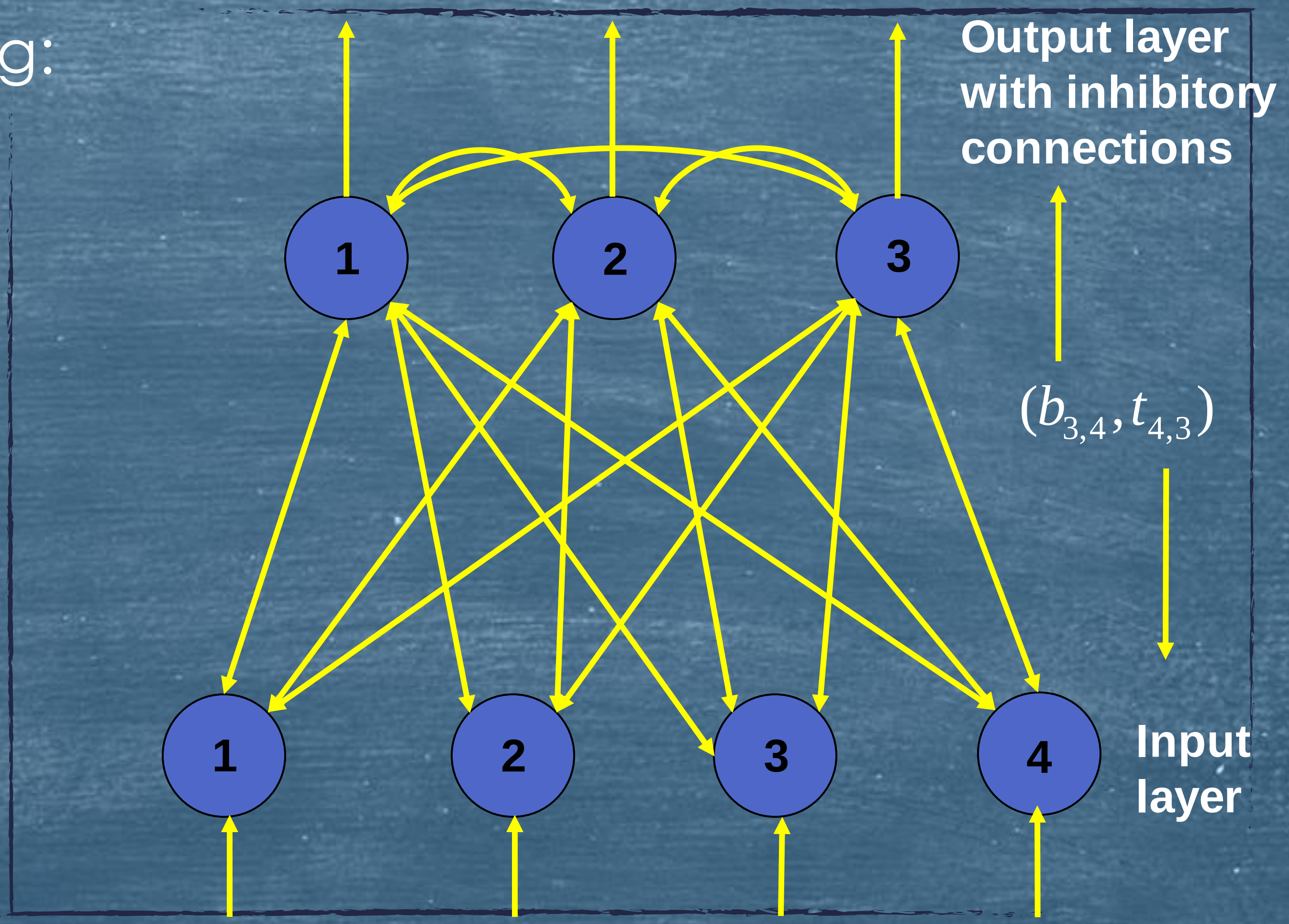
A low representation of data, good for visualization

Neural Networks History

- Unsupervised Learning:

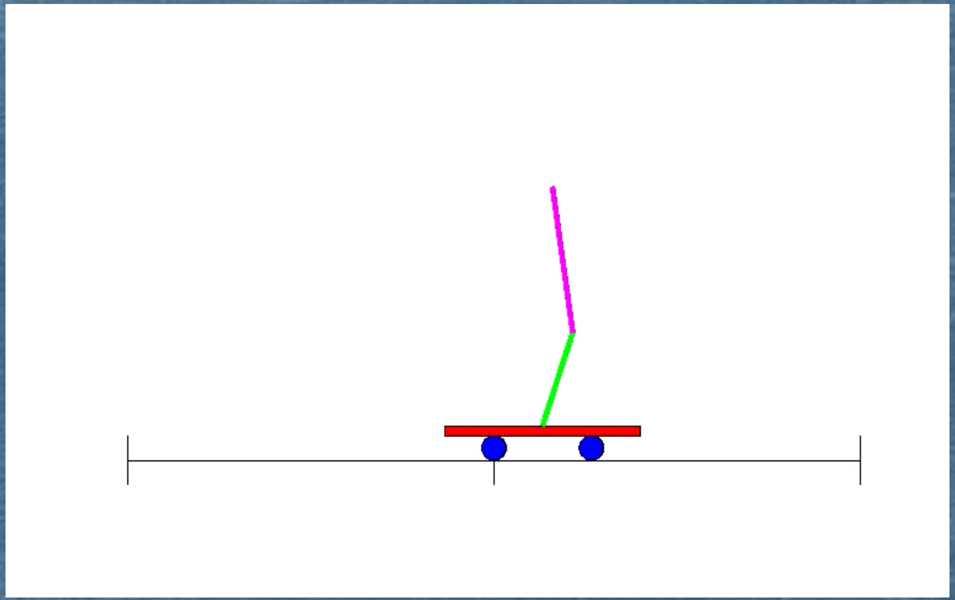
Clustering:

Adaptive Resonance Theory (classify data without giving targets)



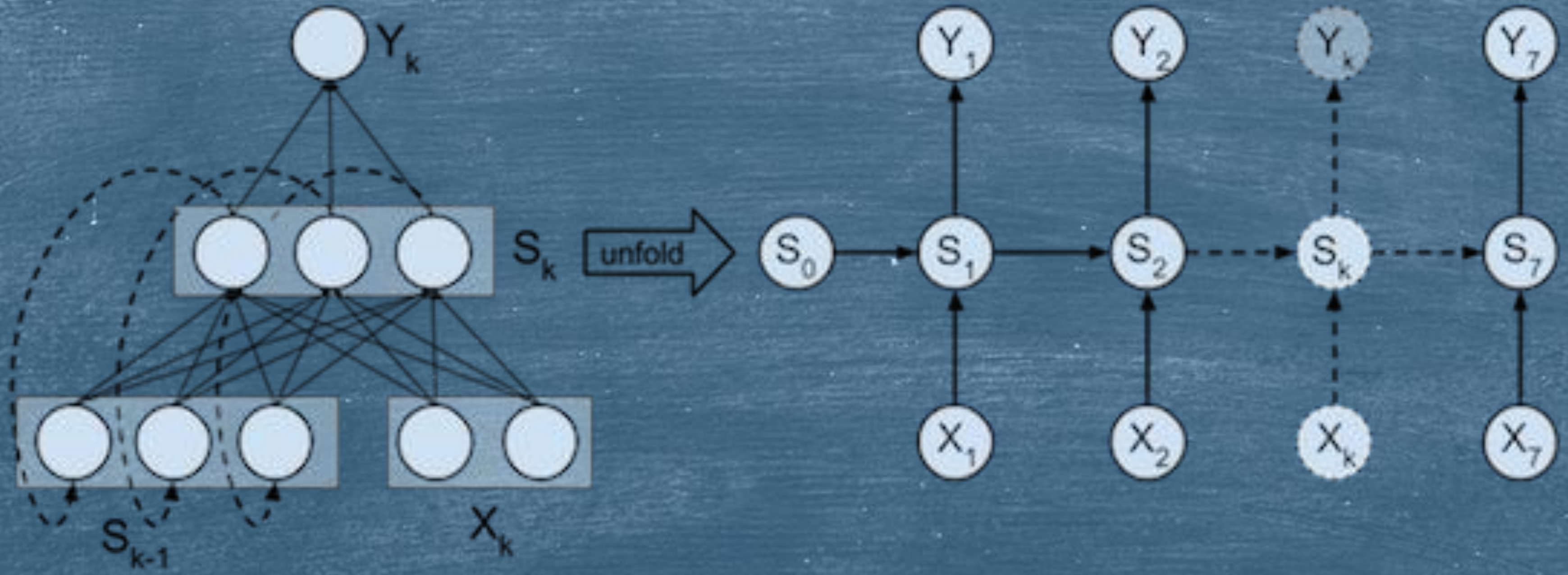
Neural Networks History

- Neural networks find its use in robotics using reinforcement learning (1990)



Neural Networks History

- Recurrent Neural Networks can remember data and finds its use in language processing (Sepp Hochreiter and Jürgen Schmidhuber)



Neural Networks History

- Deep Learning:
- 2006:Hinton, Simon Osindero, and Yee-Whye The: “A fast learning algorithm for deep belief nets”:
  - Neural networks with many layers can be trained good, if weights aren’t set random
  - Unsupervised learning combined with supervised learning (semi-supervised learning)

Neural Networks History

- Abdel-rahman Mohamed, George Dahl, and Geoff Hinton:Deep Belief Networks for phone recognition
  - Neural networks make use GPU power

- Using just more data and GPU power, neural networks achieve 0.35% on MNISTS dataset

- George Dahl and Abdel-Rahman Mohamed get an intership at Microsoft and make use of big-data

Neural Networks History

- Google becomes interested of neural networks when Andrew Ng (Stanford University) meets Jeff Dean and they make a team called Google Brain
- One of the biggest neural networks (16000 CPU cores, 1 billion weights) to be trained on 1 million youtube videos
- Google buys DeepMind, a company that created networks capable of playing ATARI games (ex: Space Invaders, Pong)

Neural Networks History

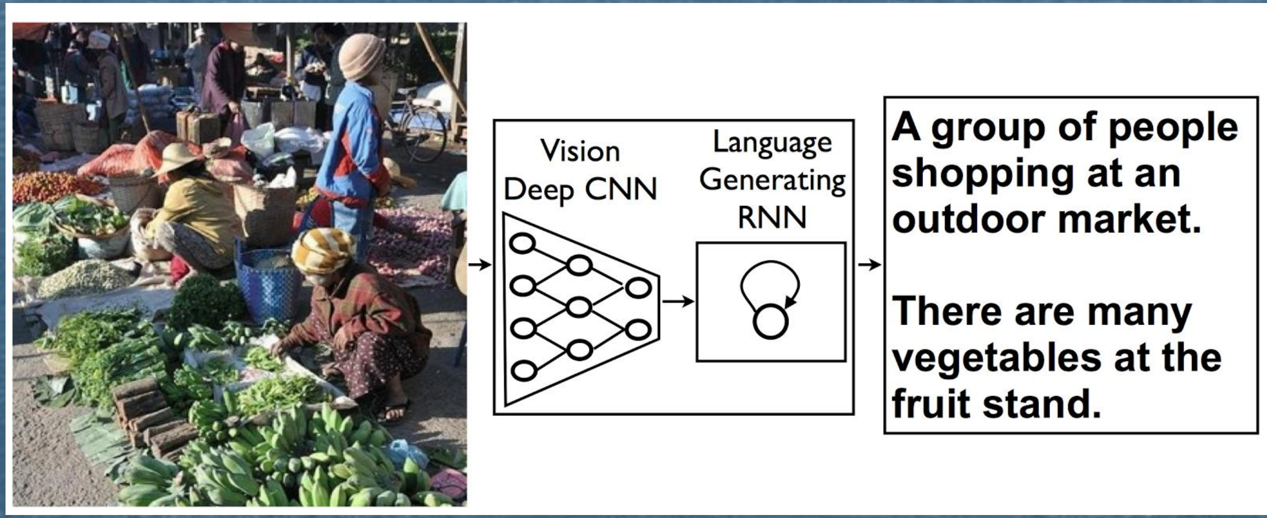
- People start to question if what they knew about neural networks is right and why didn't backpropagation work:
  - Our labeled datasets were thousands of times too small.
  - Our computers were millions of times too slow
  - We initialized the weights in a stupid way.
  - We used the wrong type of non-linearity

Neural Networks History

- In 2012 Hinton, Alex Krizhevsky and Ilya Sutskever achieved 15.3% error rate on ImageNet competition. The second place achieved 26.2%.
- CNN are now state of the art in image processing (used by Facebook for face recognition)
- The RNN are now state of the art in language processing (used by Microsoft Skype's translate)
- All of these were developed many years ago

Neural Networks History

- 2014, Google and Stanford develop a system capable of describing photos



Questions?

Bibliography

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