University of Minho
School of Engineering

ISLab

Artificial Neural Networks

Connective Systems and Classifiers

Perfil ML:FA @ MiEI/4º ano - 2º Semestre
Bruno Fernandes, Victor Alves, Cesar Analide

27/02/2020

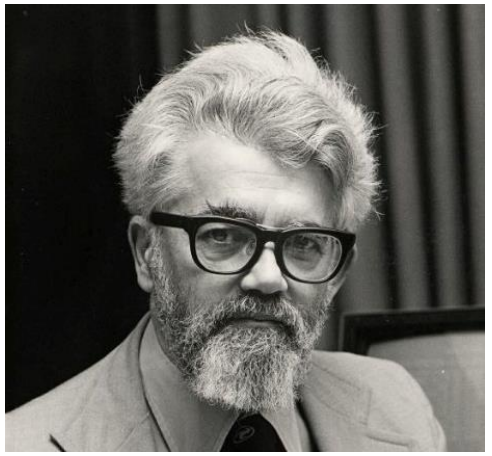
Contents

- Concepts
- And/Or/XOR
- Training Example

Some Definitions

"Every aspect of learning or any other feature of intelligence can in principle be so precisely described that a machine can be made to simulate it.
An attempt will be made to find how to make machines use language, form abstractions and concepts, solve kinds of problems now reserved for humans, and improve themselves."

John McCarthy, Dartmouth Conference, 1956

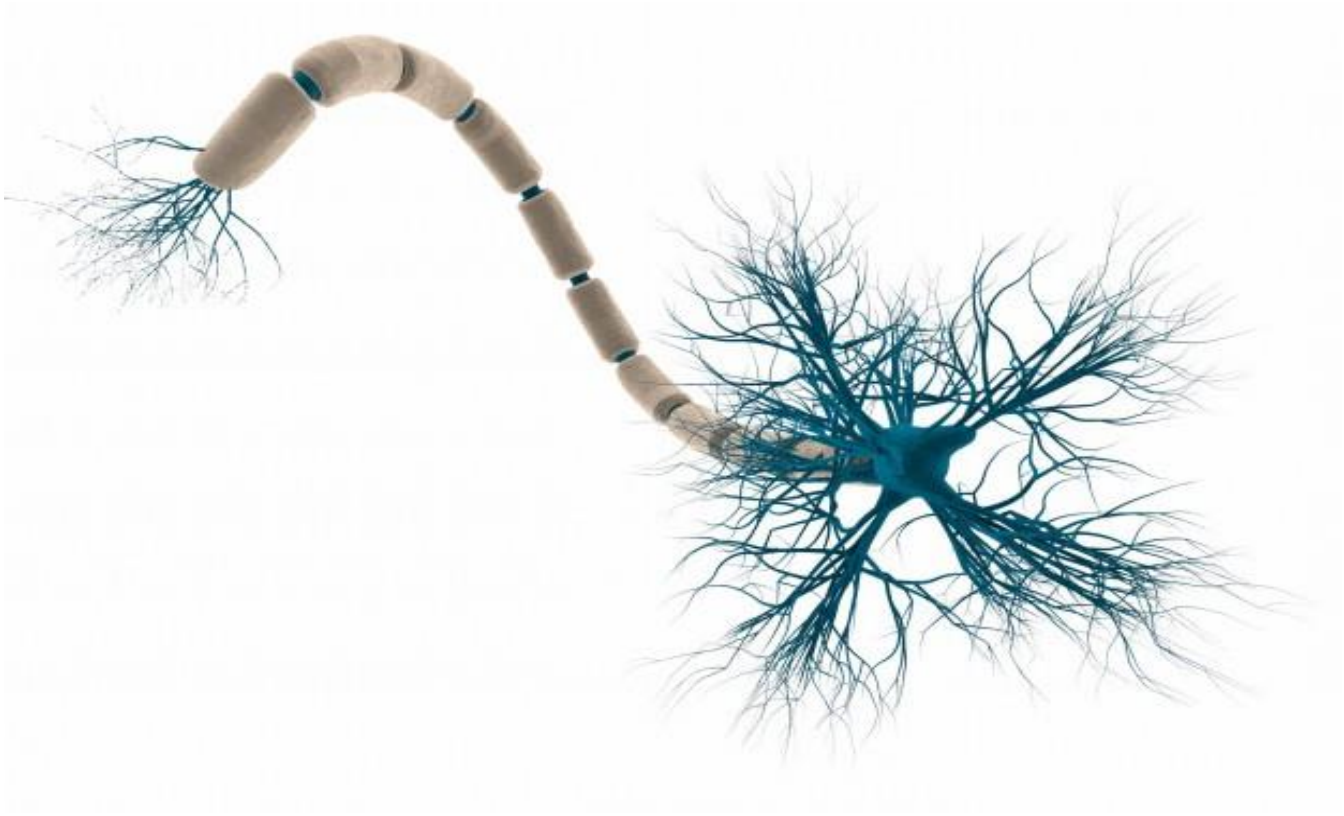


Some Definitions

"Machine learning is an application of artificial intelligence that provides systems the ability to automatically learn and improve from experience without being explicitly programmed."

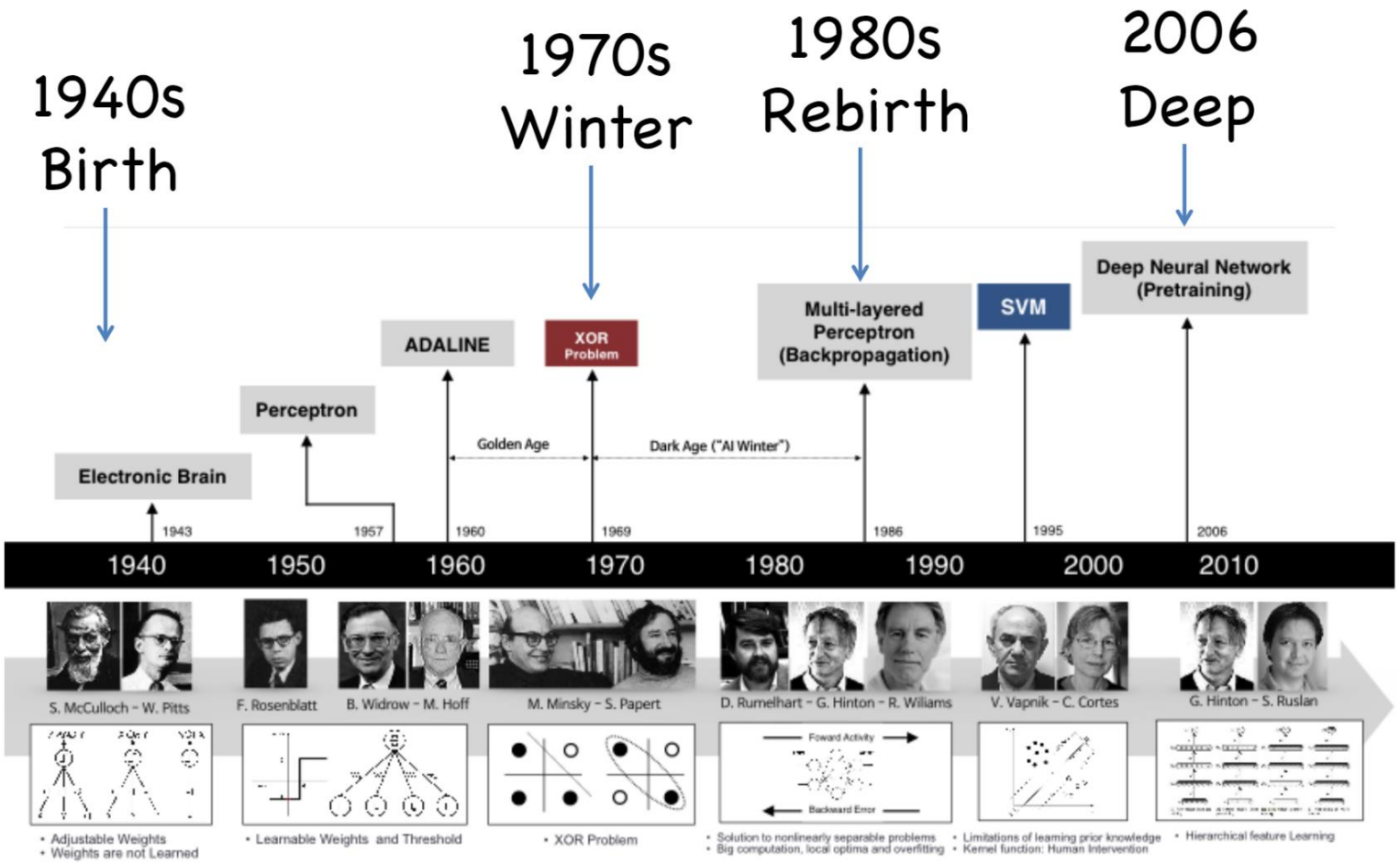
Marco Varone et al. (https://www.expertsystem.com/machine-learning-definition)

Neurons



You may want to watch:
https://www.youtube.com/watch?v=aircAruvnKk

Evolution

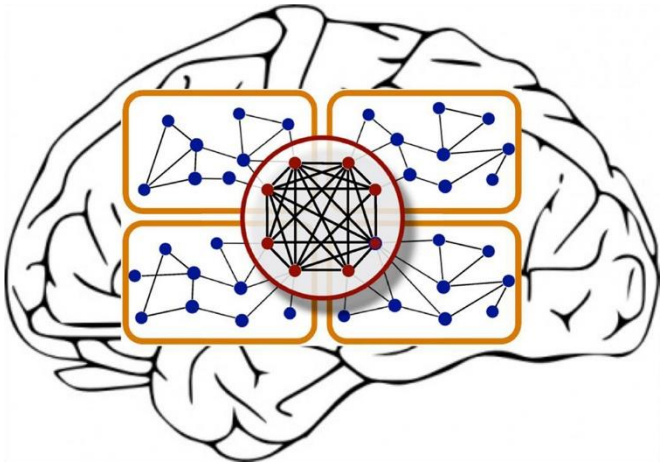


(https://github.com/qingkaikong/20161202_ANN_basics)

Artificial Neural Networks

Definition

- An Artificial Neural Network (ANN) is a computational system based on connections for problem solving
- An ANN is conceived as a simplified model of the central nervous system of human beings!
- ANNs are defined by a interconnected structure of computational units, called neurons



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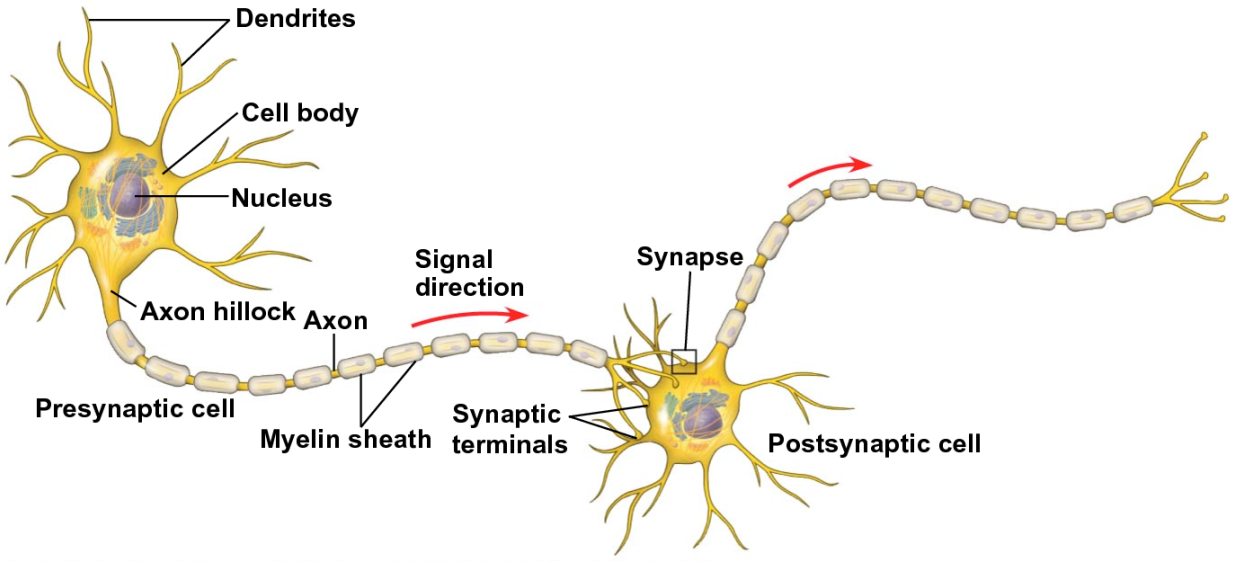


Artificial Neural Networks

The Human Brain

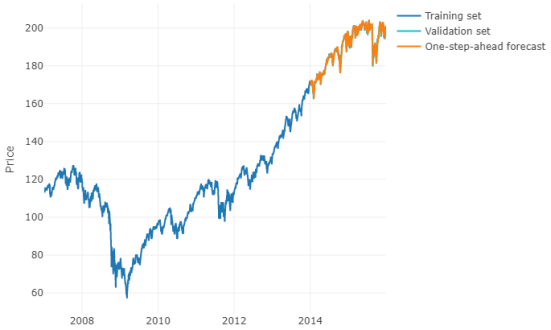
- 100.000.000.000 neurons
- 10.000 entries per neuron
- 1 electrochemical signal in each neuron
- Neurons are connected via chemical neurotransmitters (dopamine, serotonin, glutamate, gamma-aminobutyric)
- Represents 2% of the mass of the human body
- Receives 25% of the blood pumped by the heart

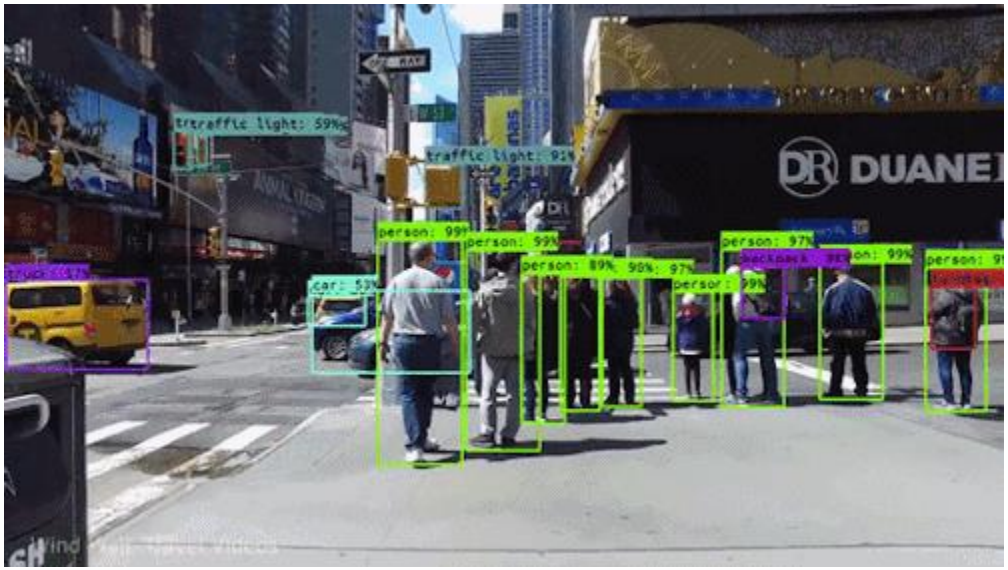
Artificial Neural Networks

Examples

ANNs are being used for:

- Fraud Detection
- Audio recognition
- Text-to-speech
- Text translation
- Image Classification
- Object Detection
- Time Series
- …





Artificial Neural Networks

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- …

The system starts with one neural network that knows nothing about the game of Go. It then plays games against itself, by combining this neural network with a search algorithm. As it plays, the neural network is tuned and updated to predict moves, as well as the eventual winner of the games.

(https://deepmind.com/blog/article/alphago-zero-starting-scratch)

Artificial Neural Networks

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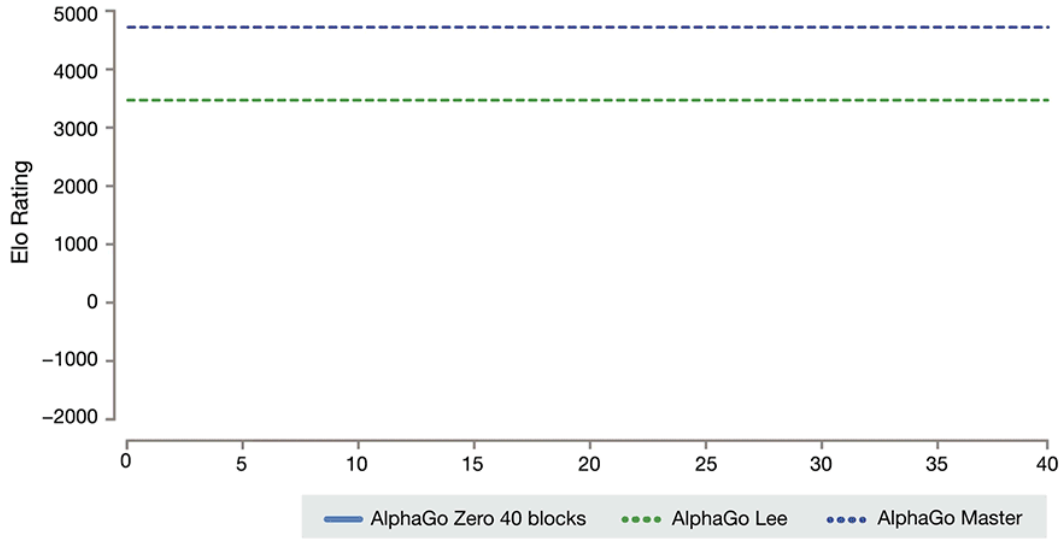
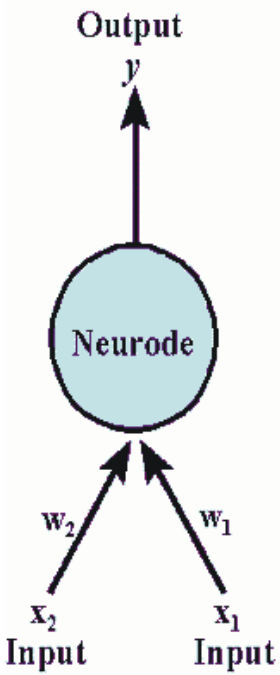


Artificial Neural Networks

And

- Perceptron (around 1960)



p	q	and
T	T	T
T	F	F
F	T	F
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(https://web.csulb.edu/~cwallis/artificialn/History.htm)

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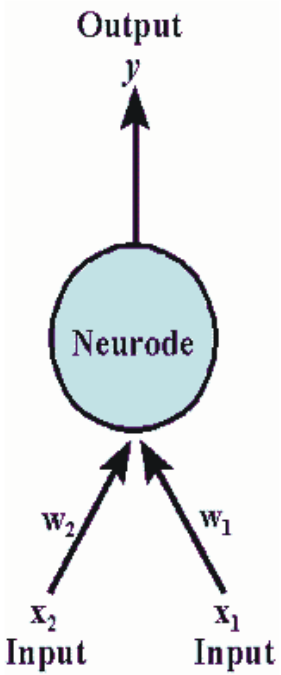

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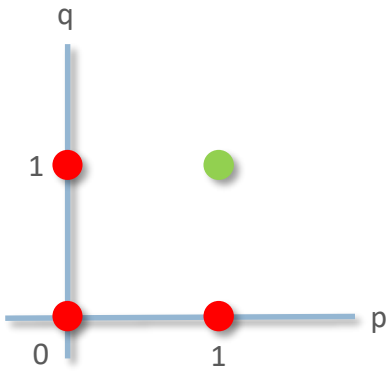

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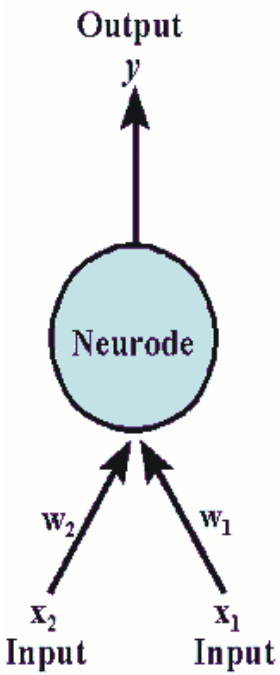

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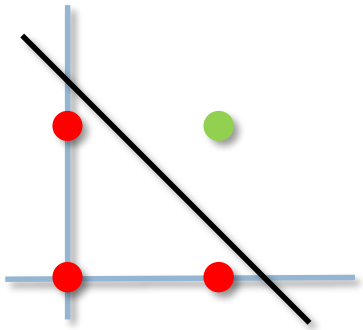

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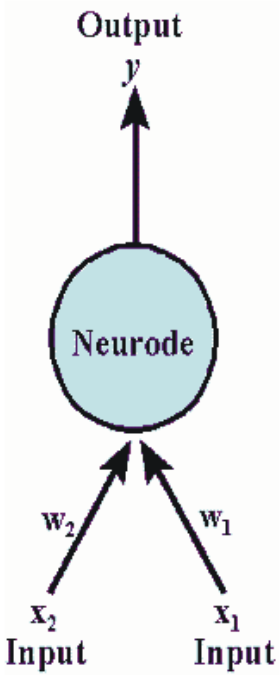

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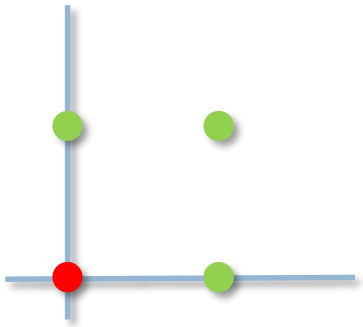

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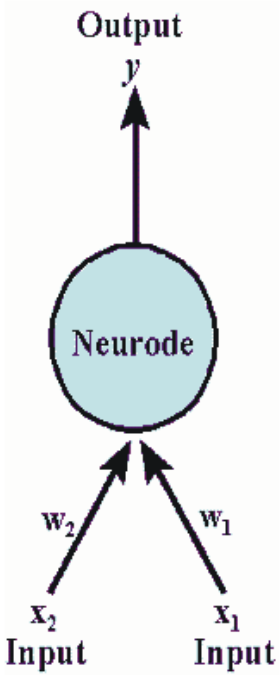

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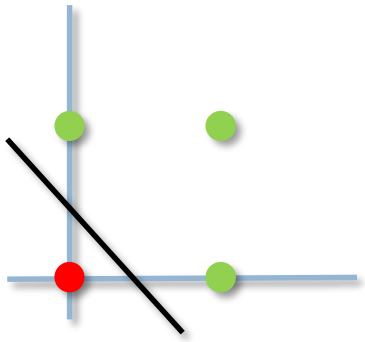

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Artificial Neural Networks
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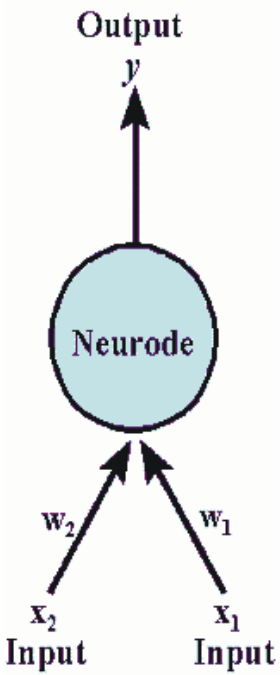

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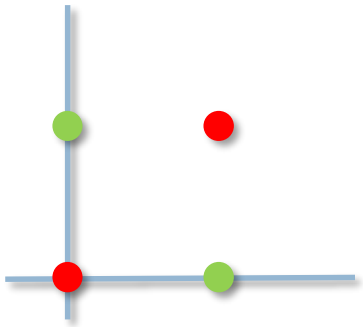

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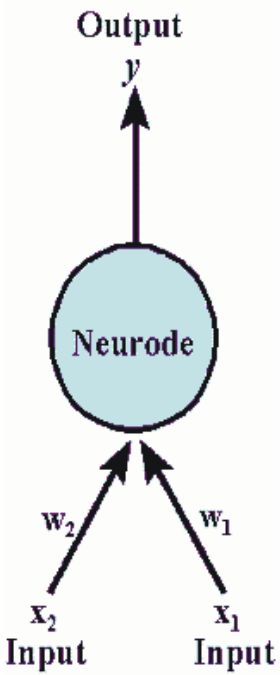

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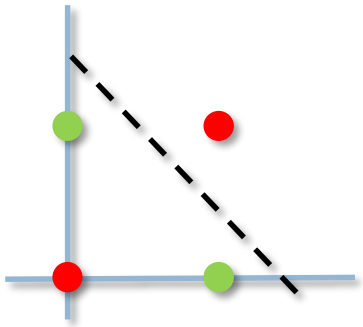

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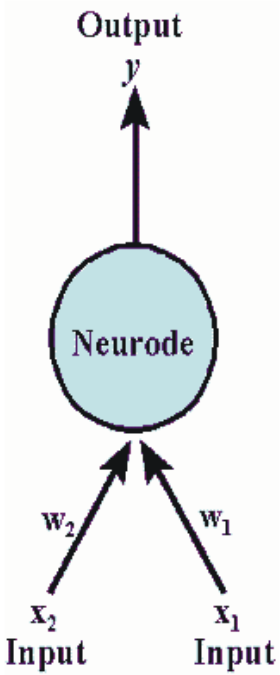

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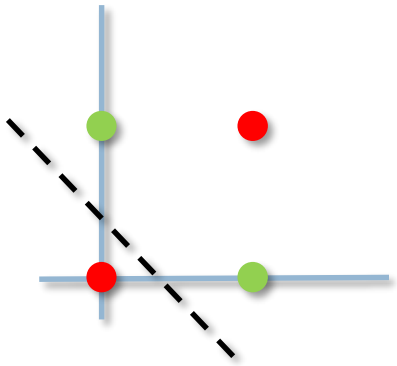

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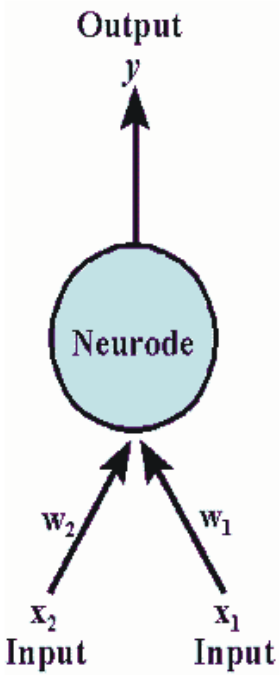

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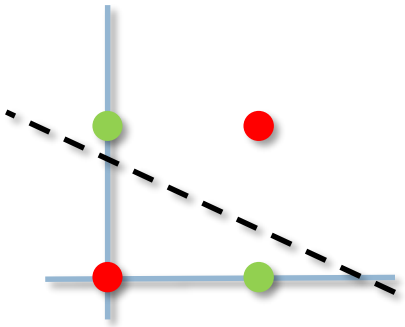

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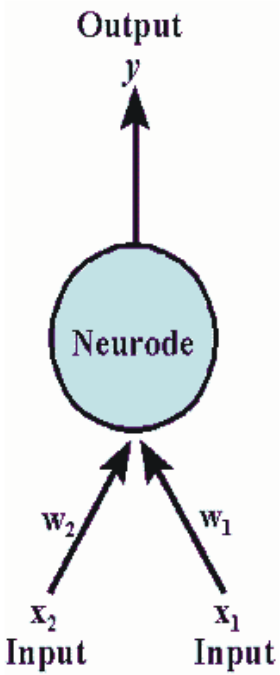

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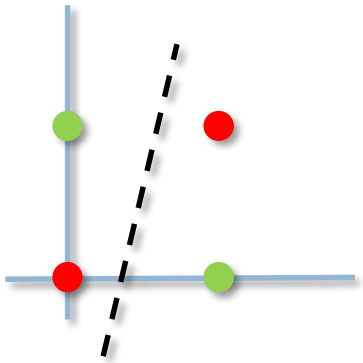

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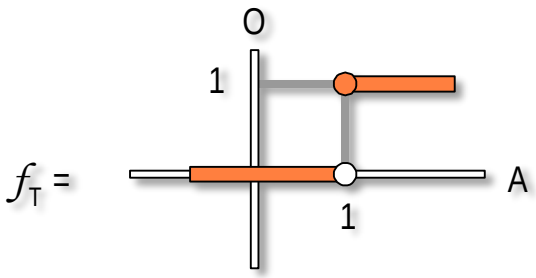
Artificial Neural Networks
XOR

- The perceptron's activation (its core value):

$$F_A = \sum input \cdot weights$$

- A non-linear Transfer function:



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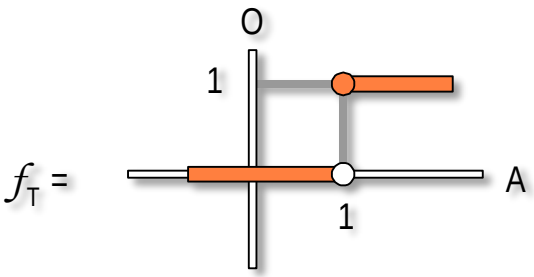
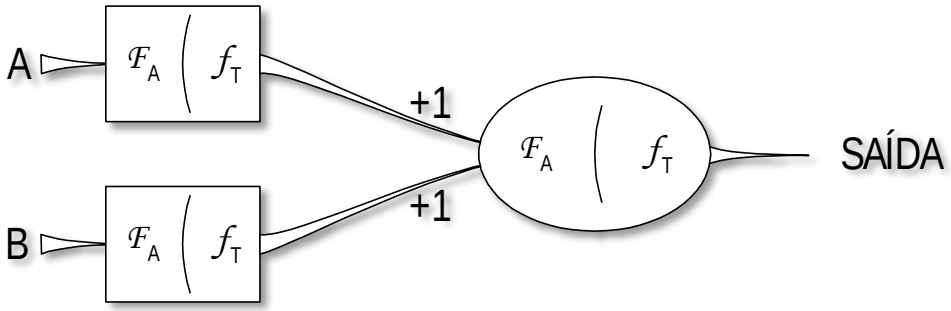


A	B	xor
1	1	0
1	0	1
0	1	1
0	0	0



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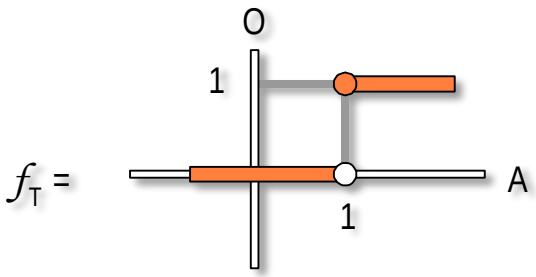

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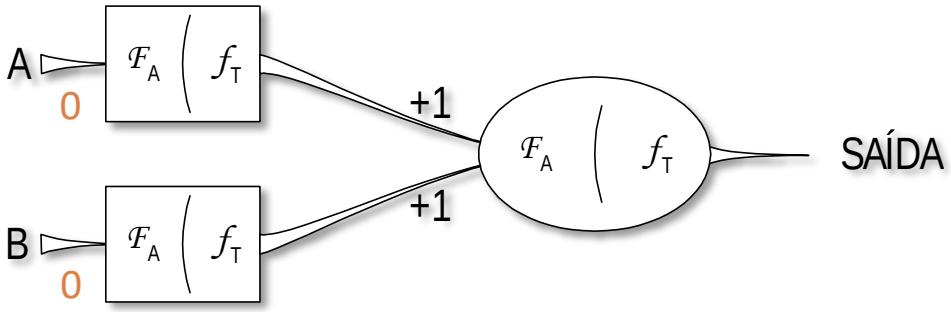

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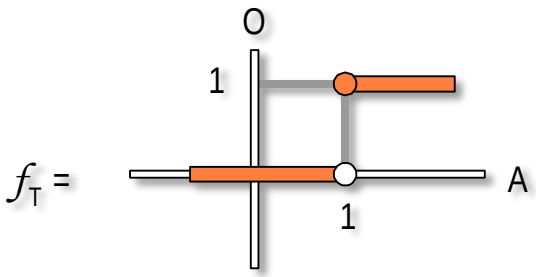

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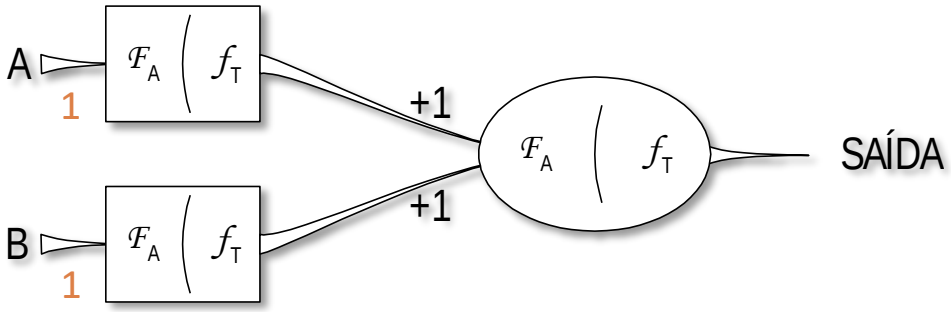

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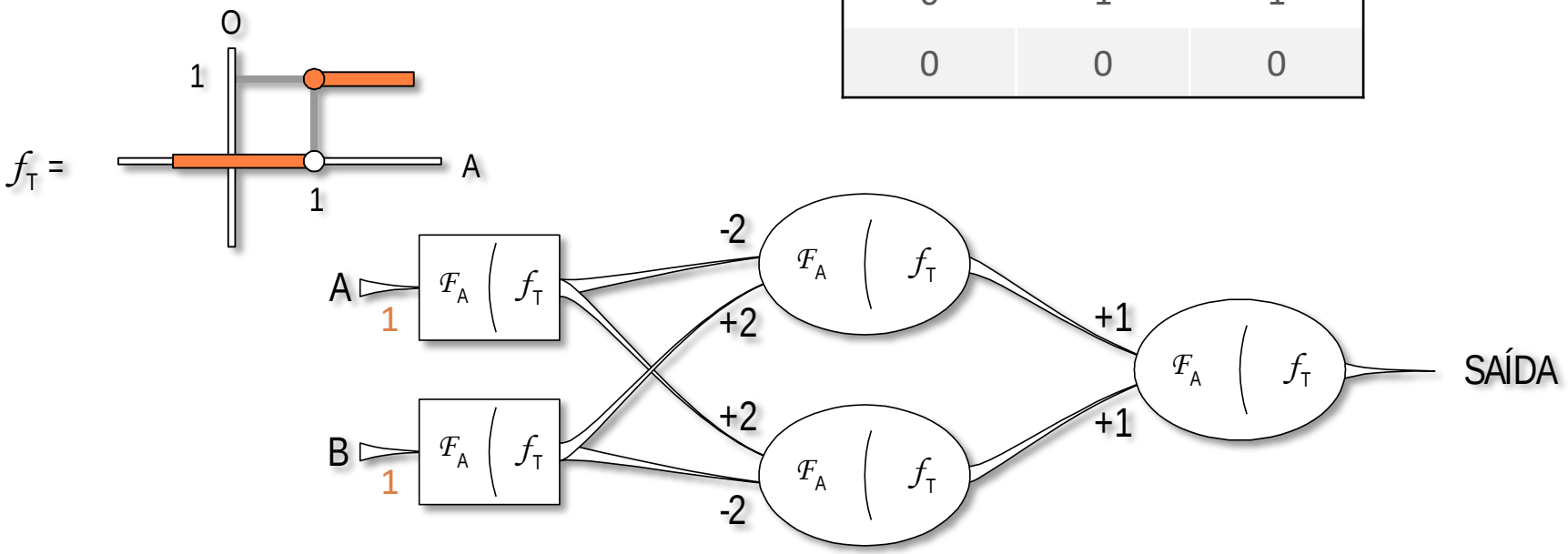
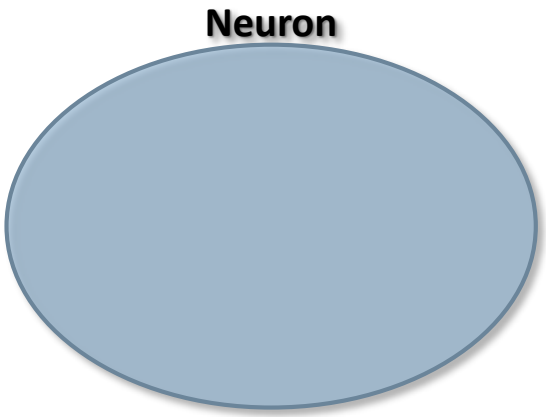


Artificial Neural Networks

Neuron

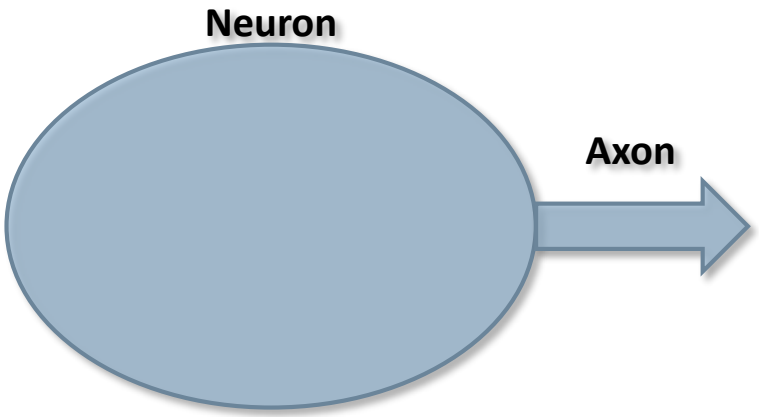
- The neuron is the computational unit of an ANN
- It is identified by its position in the network
- Characterized by the state's value



Artificial Neural Networks

Axon

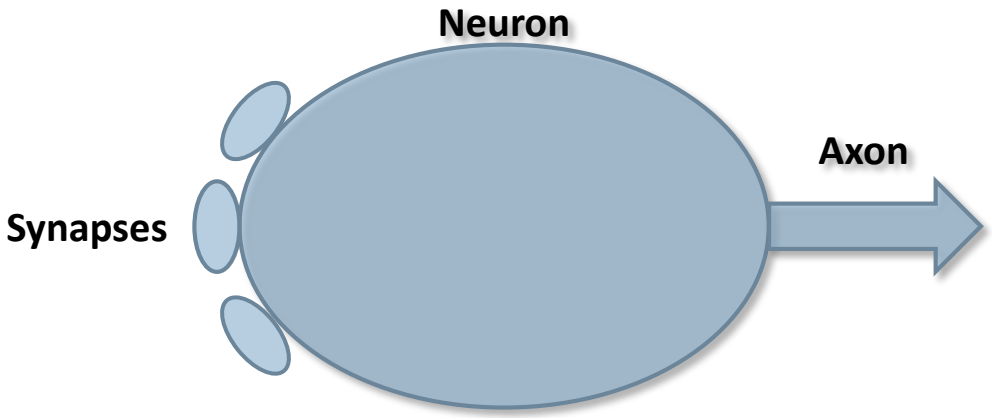
- Communication route between neurons
- It can connect to any neuron (including itself)
- Information flows through the axon



Artificial Neural Networks

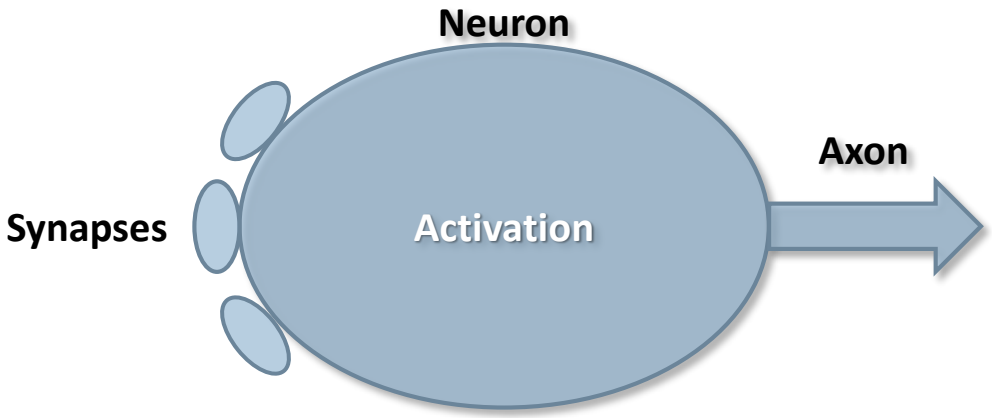
Synapse

- Connection point between axons and neurons
- The synapse value determines the weight (importance) of the signal to enter the neuron: excitatory, inhibitory or null



Artificial Neural Networks
Activation

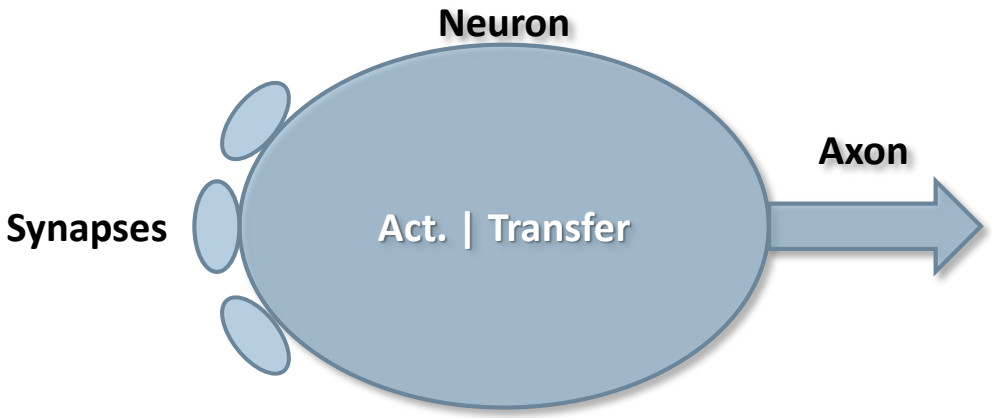
- The activation value is represented by a single value
- The activation value changes with time
- The range of values changes with the used model
  (usually depends on the inputs and some memory effect)



Artificial Neural Networks

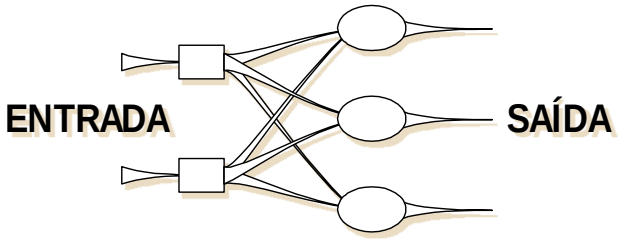
Transfer Function (aka Activation Function)

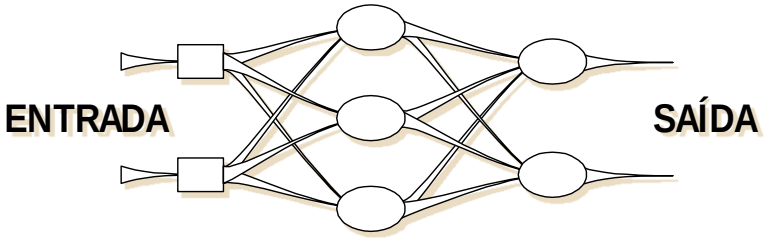
- The output of the neuron (transferred through the axon)
- It is calculated as a function of the activation value
- In reality, it is a Transfer Function as it transfers the weighted activation of the neuron. However, we will call it Activation Function
- We will see, in detail, some of these Activation Functions later!

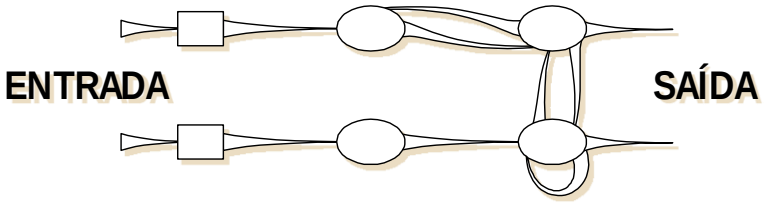


Artificial Neural Networks

Architectures







Artificial Neural Networks

Training Example

Let’s consider the following ANN…

Artificial Neural Networks

Training Example

Let's consider the following ANN…

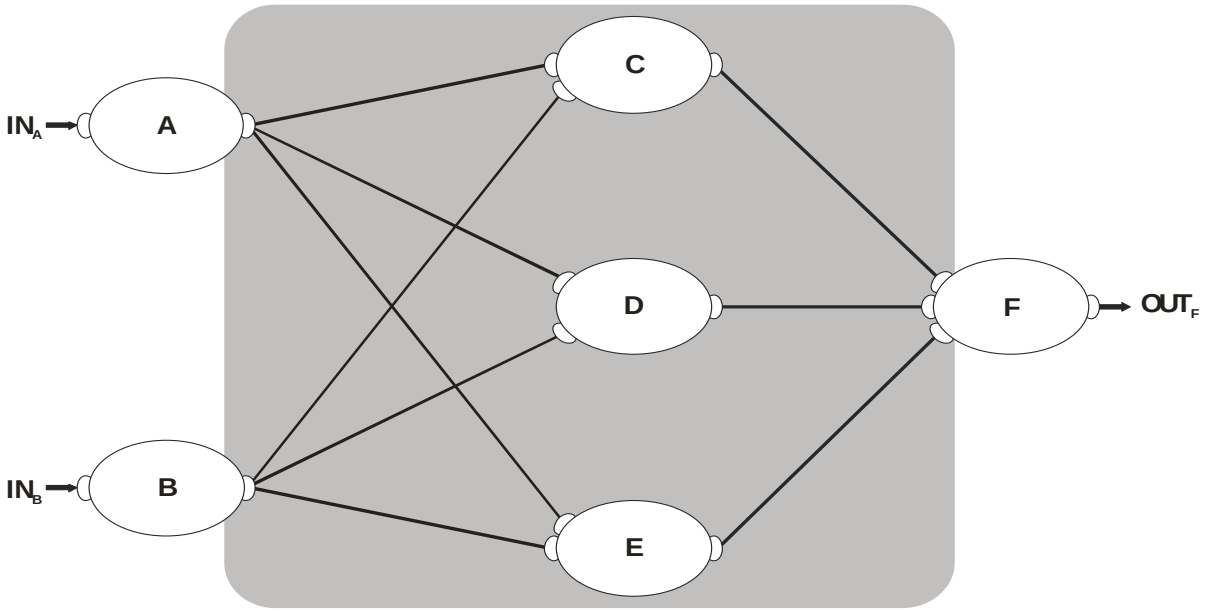
- Receiving two inputs and having one neuron as output layer

Artificial Neural Networks

Training Example

Let's consider the following ANN…

- One deep fully-connected layer

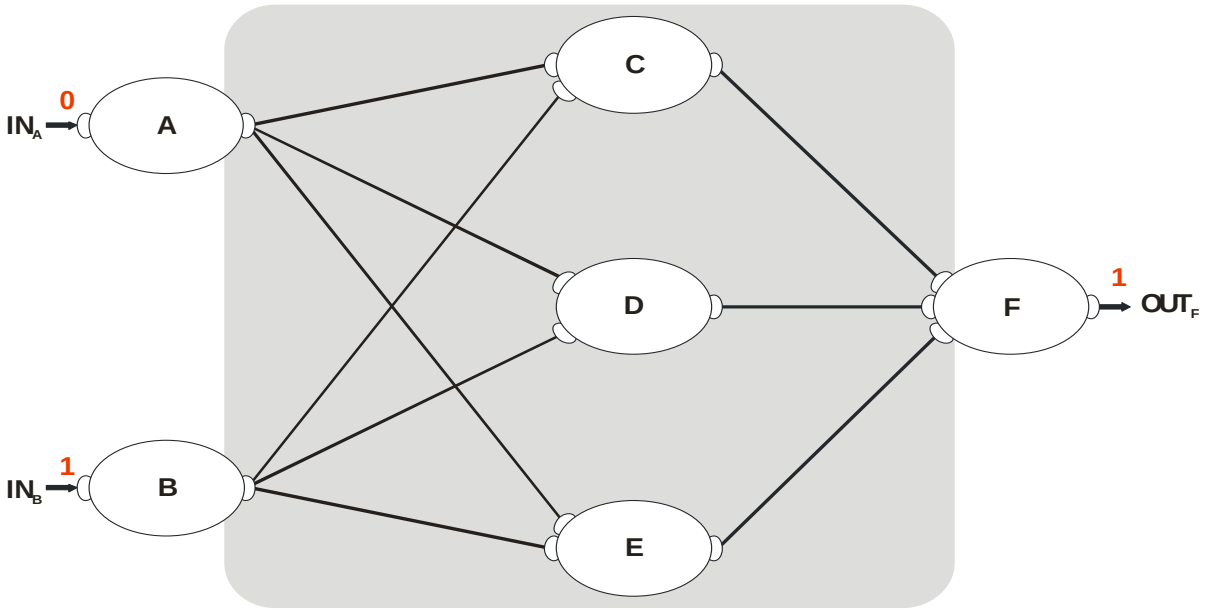


Artificial Neural Networks

Training Example

Let's consider the following ANN…

- Supervised learning as we know what the output should be!

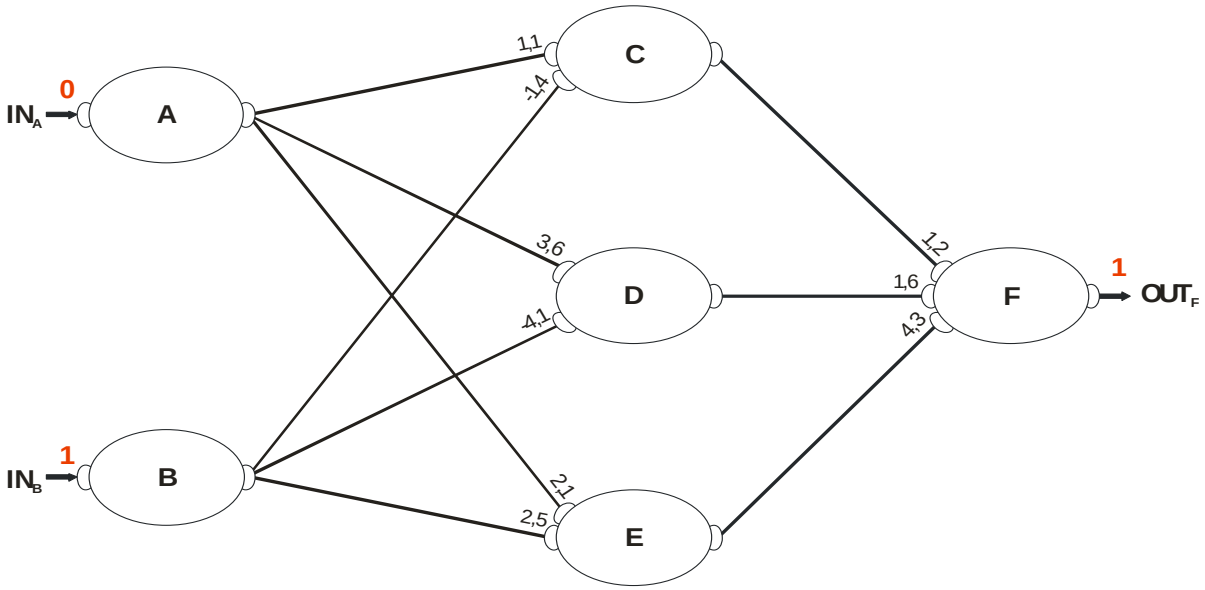


Artificial Neural Networks

Training Example

Let's consider the following ANN…

- Randomly initializing the weights of synapses (to small random numbers)



$$f_A(P,E) = \sum P \times E$$

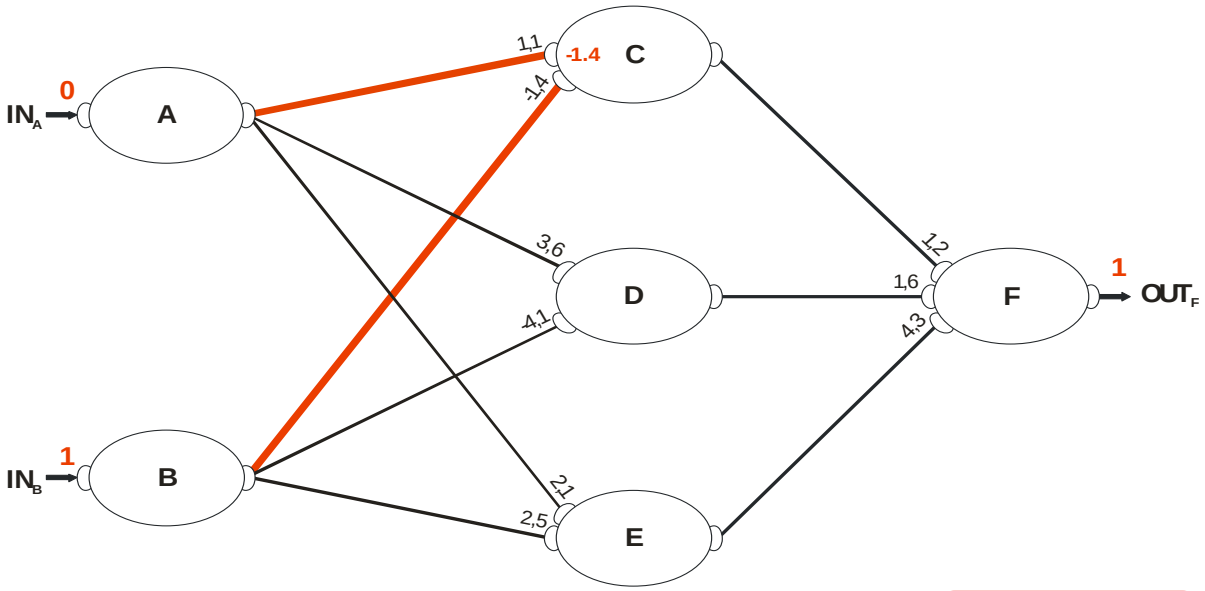
$$f_T(A) = A$$

Artificial Neural Networks

Training Example

Let's consider the following ANN…

- Data flow throughout the network (forward pass)



$$f_A(P,E) = \sum P \times E$$

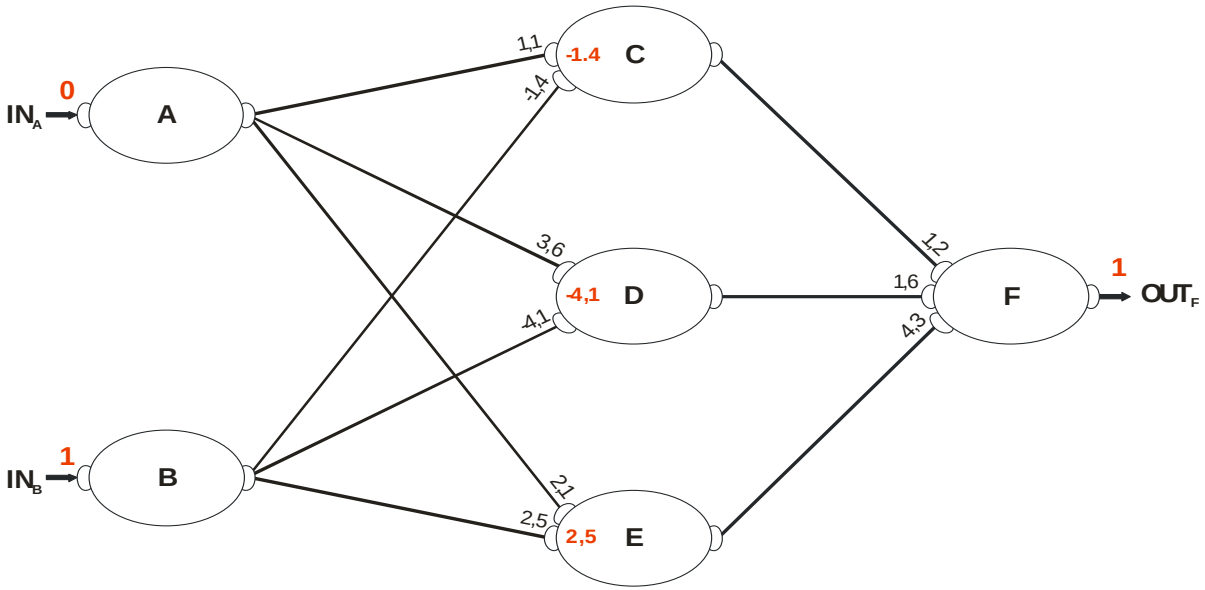
$$f_T(A) = A$$

Artificial Neural Networks

Training Example

Let's consider the following ANN…

- Data flow throughout the network… to all neurons!



$$f_A(P,E) = \sum P \times E$$

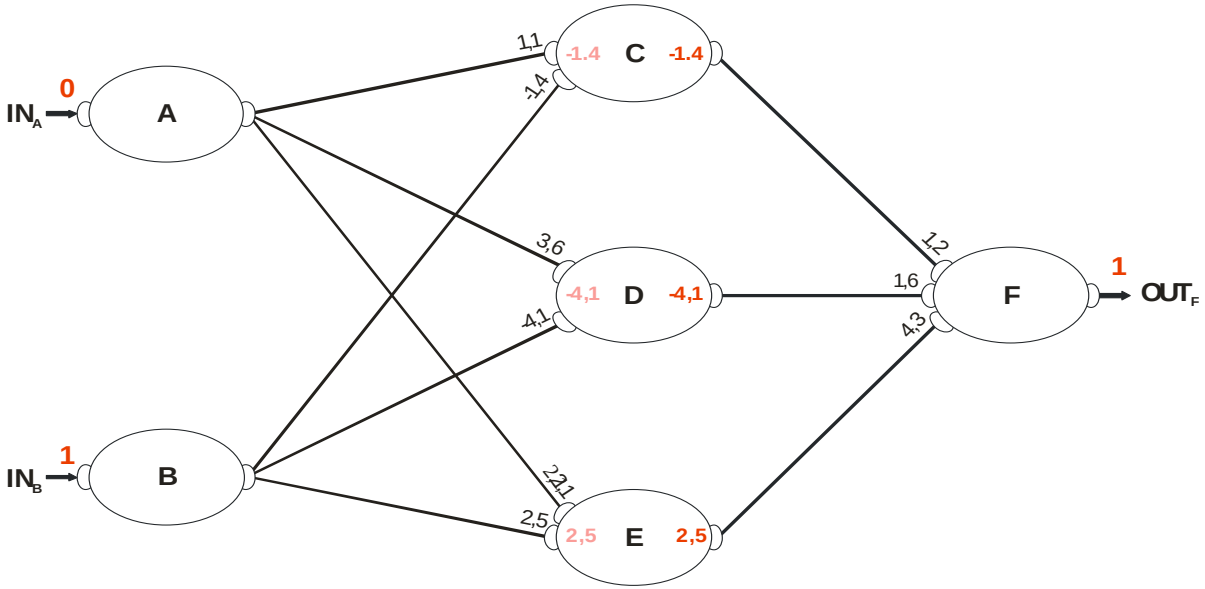
$$f_T(A) = A$$

Artificial Neural Networks

Training Example

Let's consider the following ANN…

- Activation value (identity function for simplicity reasons)!



$$f_A(P,E) = \sum P \times E$$

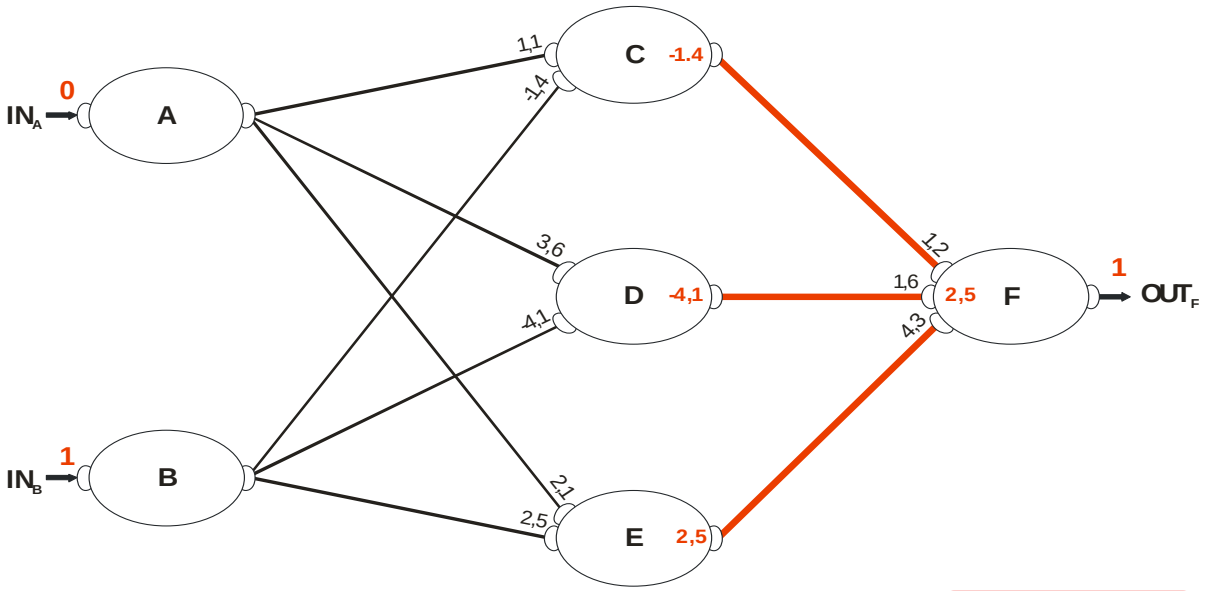
$$f_T(A) = A$$

Artificial Neural Networks

Training Example

Let's consider the following ANN…

- Exactly the same process for the next layer…



$$f_A(P,E) = \sum P \times E$$

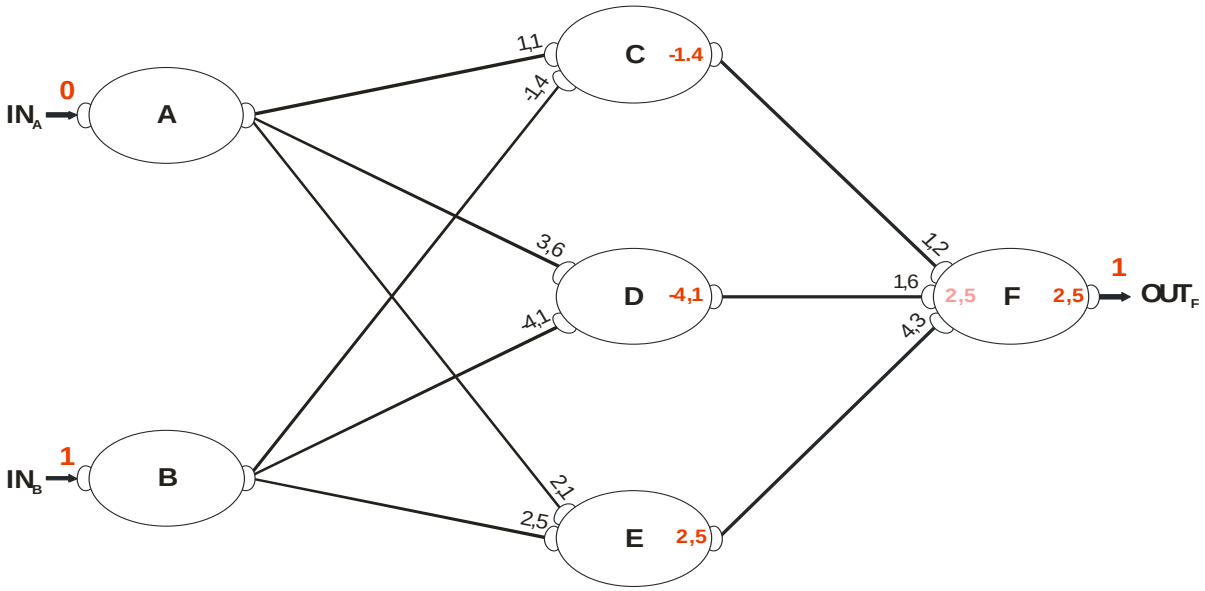
$$f_T(A) = A$$

Artificial Neural Networks

Training Example

Let's consider the following ANN…

- Exactly the same process for the next layer…



$$f_A(P,E) = \sum P \times E$$

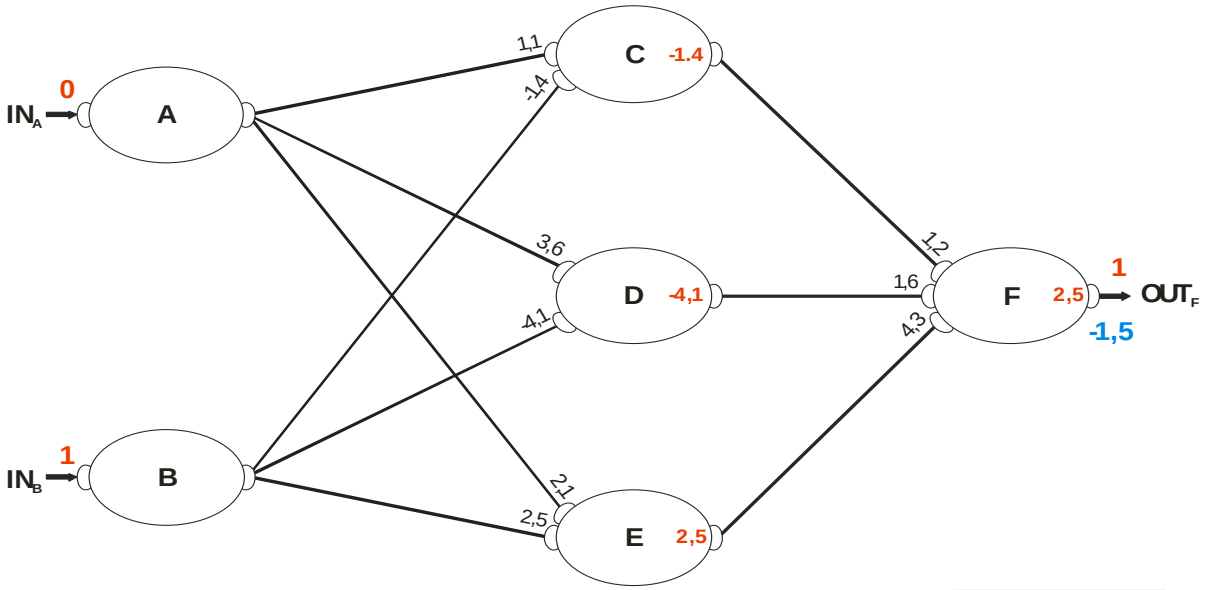
$$f_T(A) = A$$

Artificial Neural Networks

Training Example

Let's consider the following ANN…

- How far are we from the expected result? Let's calculate the error… Usually, using error functions such as MSE, RMSE, Categorical Cross-entropy, …



$$\mathcal{E} = OUT_{\mathcal{D}} - OUT_{C}$$

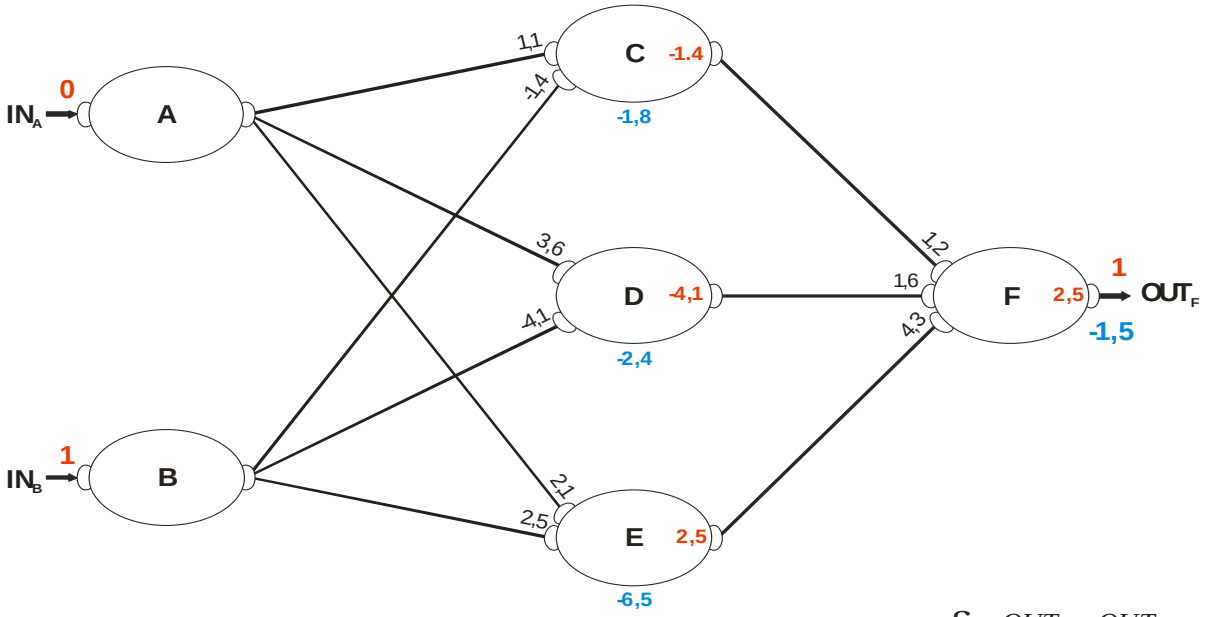
$$\mathcal{E}_{\leftarrow} = \mathcal{E} \times P$$

Artificial Neural Networks

Training Example

Let's consider the following ANN…

- Backpropagating the error…



$$\mathcal{E} = OUT_D - OUT_C$$

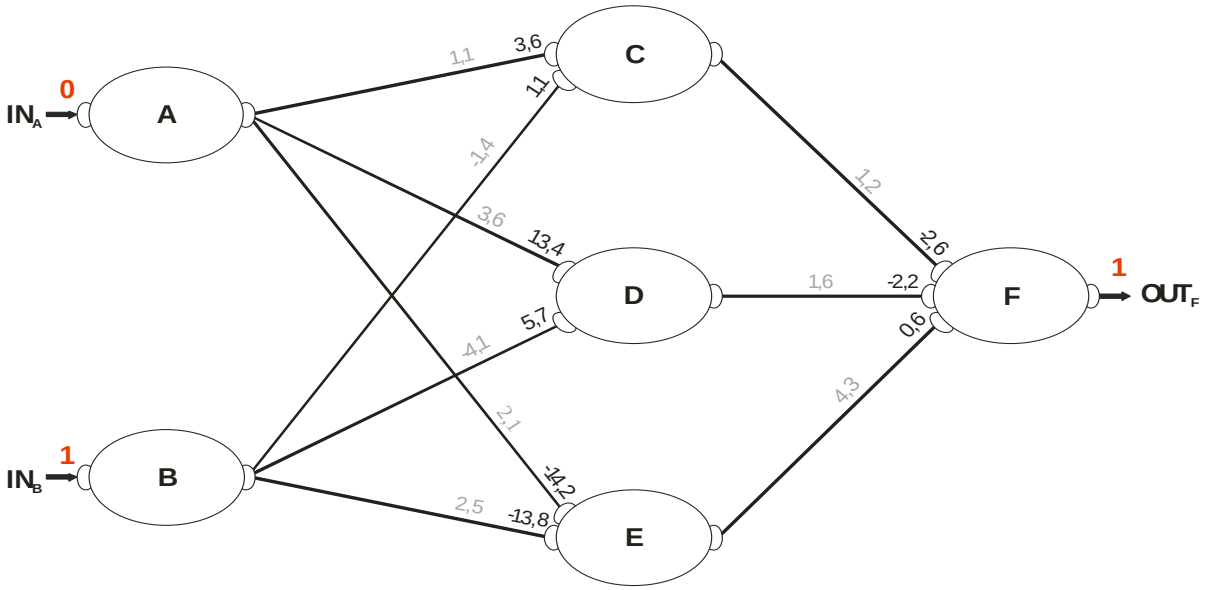
$$\mathcal{E}_{\leftarrow} = \mathcal{E} \times P$$

Artificial Neural Networks

Training Example

Let's consider the following ANN…

- Backpropagating the error… to update the weights!



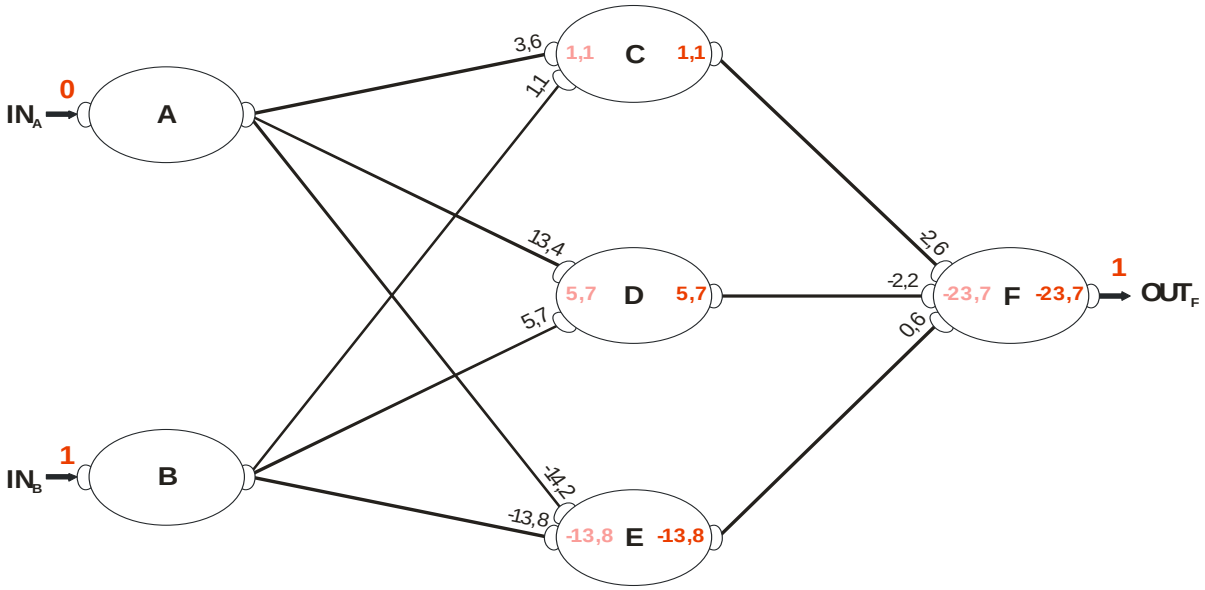
$$P_{i+1} = P_i + \varepsilon \times f_T$$

Artificial Neural Networks

Training Example

Let's consider the following ANN…

- Second iteration…



$$f_A(P,E) = \sum P \times E$$

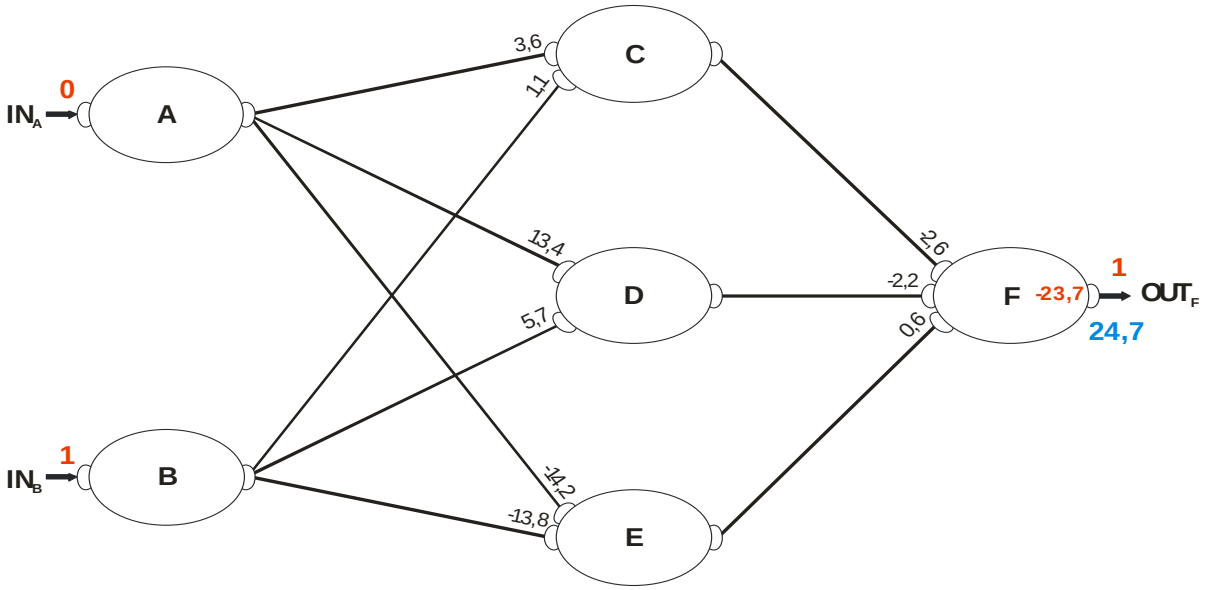
$$f_T(A) = A$$

Artificial Neural Networks

Training Example

Let's consider the following ANN…

- And the corresponding error…

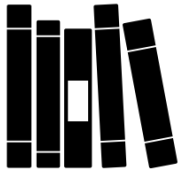


Glossary

- Neuron, Axon, Synapse, Activation Functions, and so on…

Check the previous slides for the definition of each and every one of the terms we saw today.

Resources



- Papers, Books, online courses, tutorials…
  - Cortez, P., Neves, J., “Redes Neuronais Artificiais”, Unidade de Ensino, Departamento de Informática, Universidade do Minho, 2000;
  - Haykin, S., “Neural Networks - A Comprehensive Foundation”, Prentice-Hall, New Jersey, 2nd Edition, 1999.