Perceptron Algorithm

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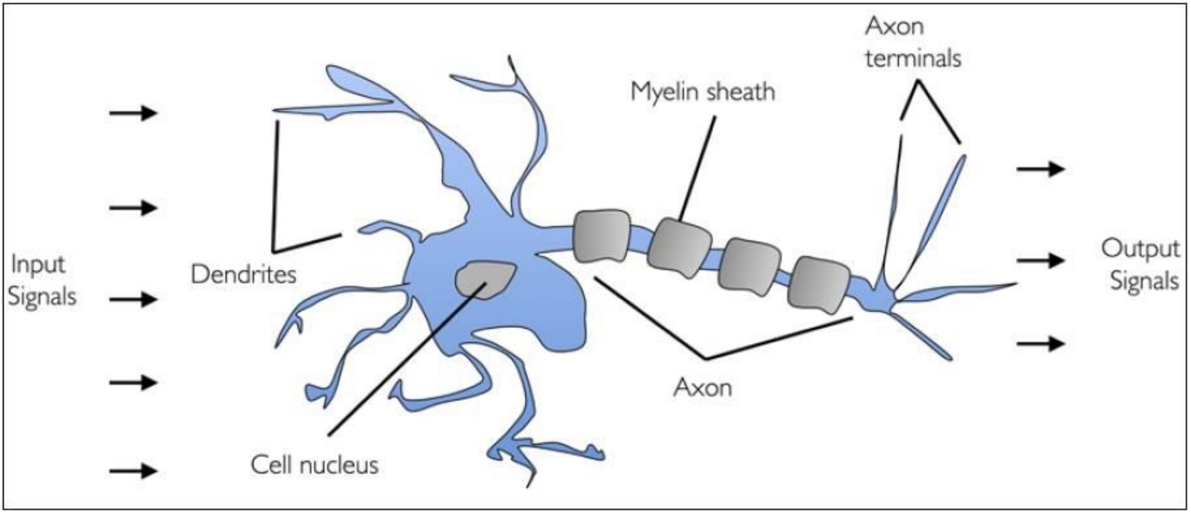
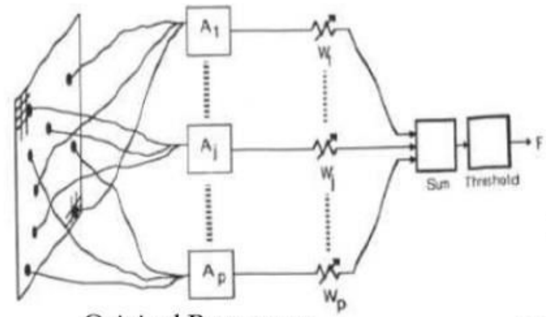
Biological Neuron

A human brain has billions of neurons. Neurons are interconnected nerve cells in the human brain that are involved in processing and transmitting chemical and electrical signals. Dendrites are branches that receive information from other neurons.



Rise of Artificial Neurons

Researchers Warren McCullock and Walter Pitts published their first concept of simplified brain cell in 1943. This was called McCullock-Pitts (MCP) neuron. They described such a nerve cell as a simple logic gate with binary outputs. Multiple signals arrive at the dendrites and are then integrated into the cell body, and, if the accumulated signal exceeds a certain threshold, an output signal is generated that will be passed on by the axon.



Original Perceptron

(From Perceptrons by M. L Minsky and S. Papert, 1969, Cambridge, MA: MIT Press. Copyright 1969 by MIT Press.

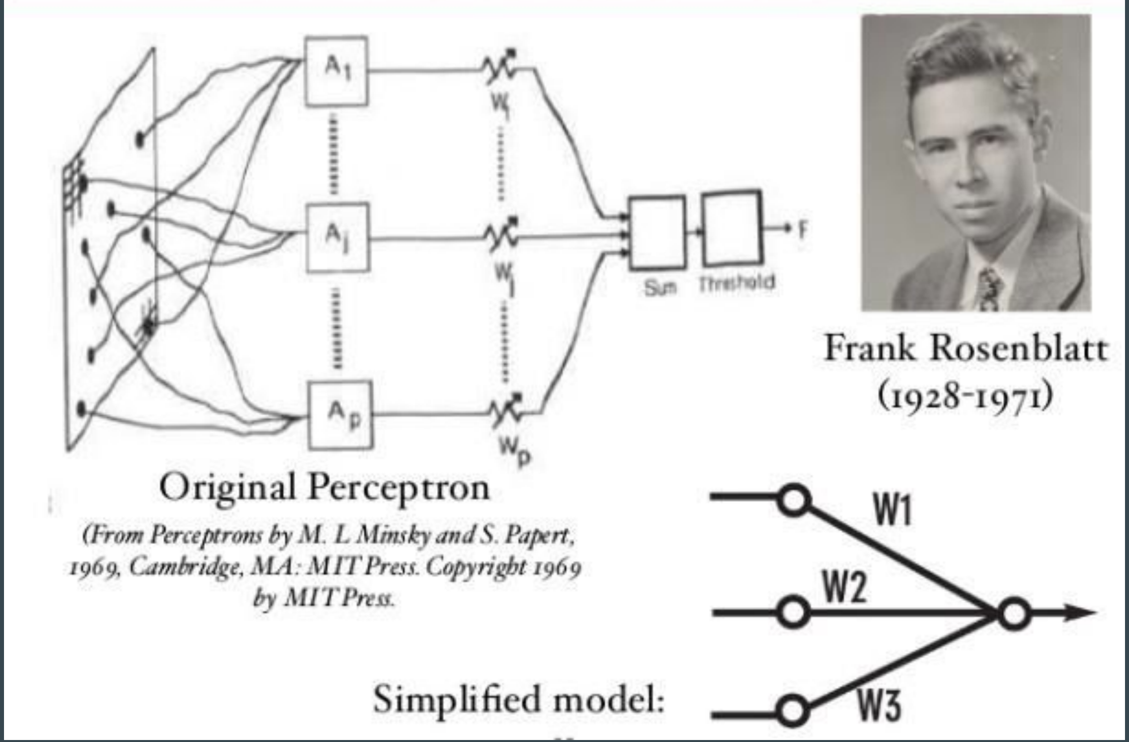
Perceptron

A perceptron is a neural network unit (an artificial neuron) that does certain computations to detect features or business intelligence in the input data.

Perceptron was introduced by Frank Rosenblatt in 1957. He proposed a Perceptron learning rule based on the original MCP neuron.

A Perceptron is an algorithm for supervised learning of binary classifiers. This algorithm enables neurons to learn and processes elements in the training set one at a time.

Perceptron cont.



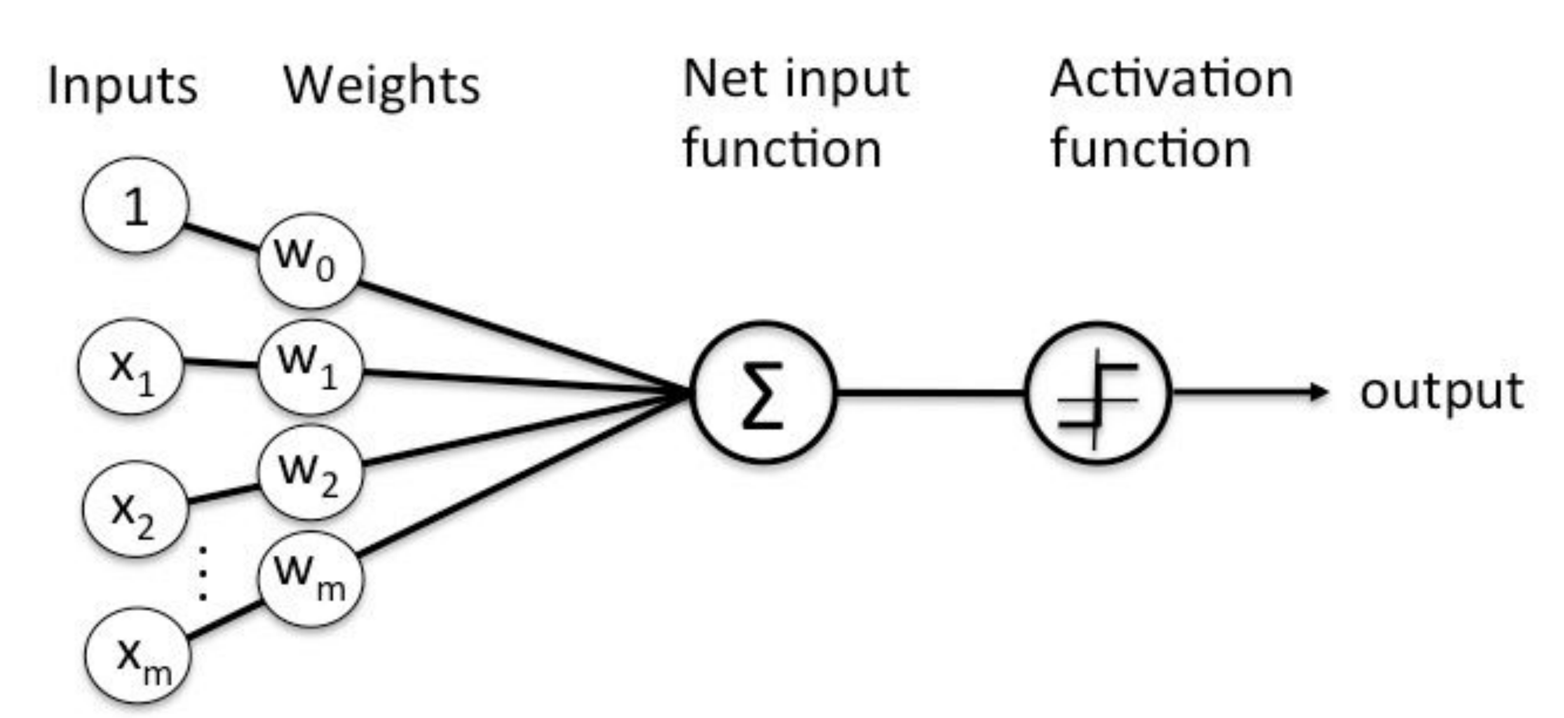
Frank Rosenblatt
(1928-1971)

Original Perceptron

(From Perceptrons by M. L Minsky and S. Papert, 1969, Cambridge, MA: MIT Press. Copyright 1969 by MIT Press.

Simplified model:

Perceptron algorithm

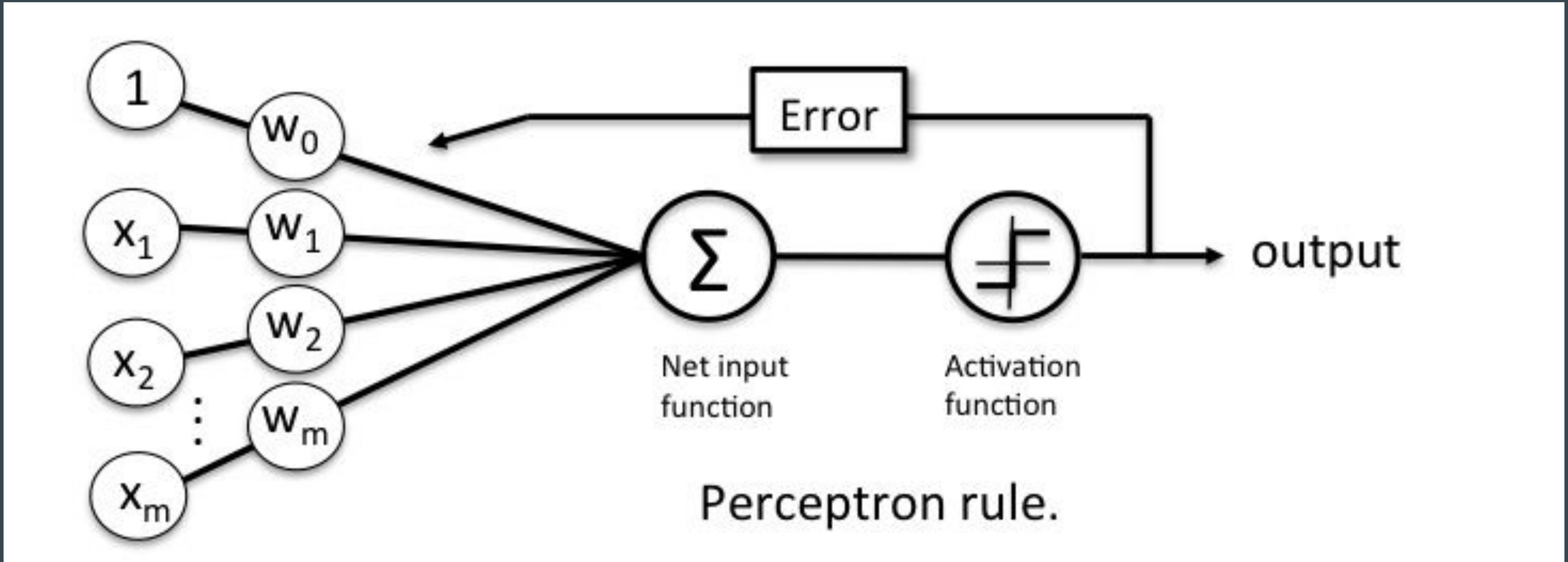


Perceptron Learning Rule

Perceptron Learning Rule states that the algorithm would automatically learn the optimal weight coefficients. The input features are then multiplied with these weights to determine if a neuron fires or not.

The Perceptron receives multiple input signals, and if the sum of the input signals exceeds a certain threshold, it either outputs a signal or does not return an output. In the context of supervised learning and classification, this can then be used to predict the class of a sample.

Perceptron Learning Rule



Perceptron rule.

Perceptron Function

Perceptron is a function that maps its input “x,” which is multiplied with the learned weight coefficient; an output value ”f(x)”is generated.

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

In the equation given above:
“w” = vector of real-valued weights
“b” = bias (an element that adjusts the boundary away from origin without any dependence on the input value)
“x” = vector of input x values

$$\sum_{i=1}^{m} w_i x_i$$

“m” = number of inputs to the Perceptron
The output can be represented as “1” or “0.” It can also be represented as “1” or “-1” depending on which activation function is used.

Perceptron Input

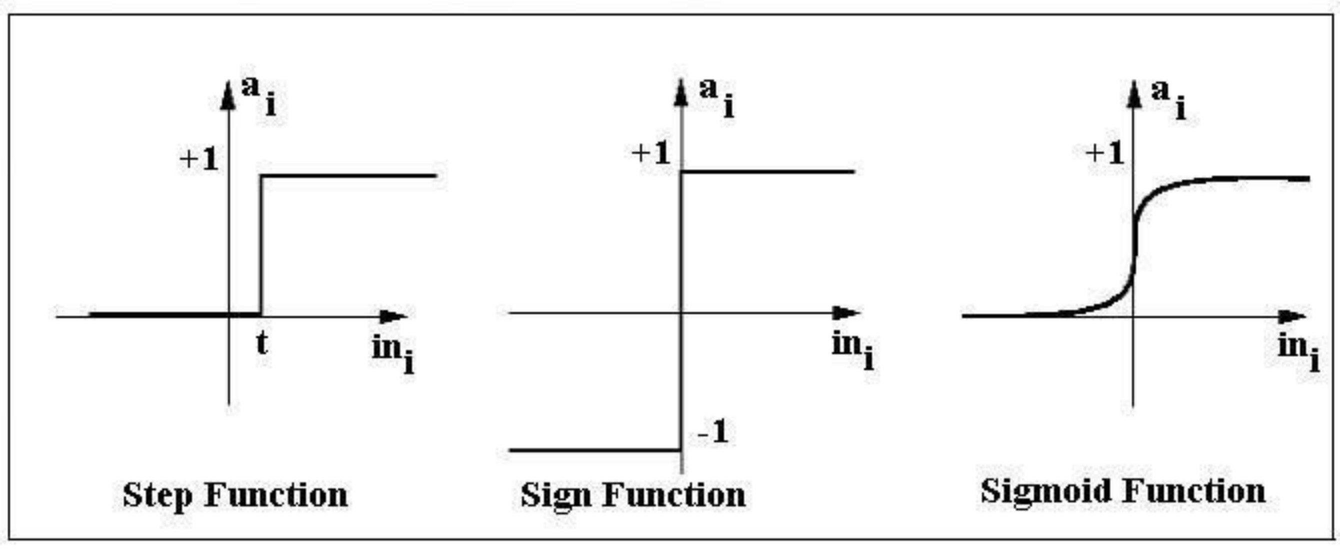
A Perceptron accepts inputs, moderates them with certain weight values, then applies the transformation function to output the final result. The above below shows a Perceptron with a Boolean output.

A Boolean output is based on inputs such as salaried, married, age, past credit profile, etc. It has only two values: Yes and No or True and False. The summation function “∑” multiplies all inputs of “x” by weights “w” and then adds them up as follows:

$$w_0 + w_1 x_1 + w_2 x_2 + \cdots + w_n x_n$$

Activation Functions of Perceptron

The activation function applies a step rule (convert the numerical output into +1 or -1) to check if the output of the weighting function is greater than zero or not.



Activation Functions of Perceptron cont.

For example:

If $\sum$ wixi> 0 => then final output “o” = 1 (issue bank loan)

Else, final output “o” = -1 (deny bank loan)

Step function gets triggered above a certain value of the neuron output; else it outputs zero. Sign Function outputs +1 or -1 depending on whether neuron output is greater than zero or not. Sigmoid is the S-curve and outputs a value between 0 and 1.

Logic Gate

- Logic gates are the building blocks of a digital system, especially neural network. In short, they are the electronic circuits that help in addition, choice, negation, and combination to form complex circuits.
- Using the logic gates, Neural Networks can learn on their own without you having to manually code the logic. Most logic gates have two inputs and one output.
- Each terminal has one of the two binary conditions, low (0) or high (1), represented by different voltage levels. The logic state of a terminal changes based on how the circuit processes data.

Logic Gate cont.

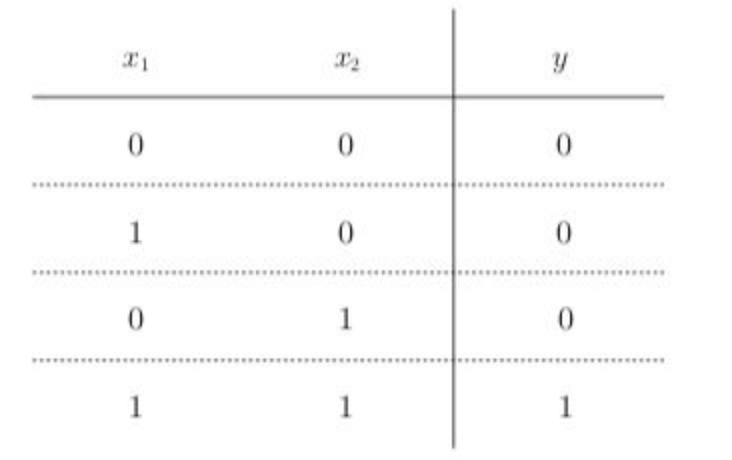
Based on this logic, logic gates can be categorized into seven types:

- AND
- NAND
- OR
- NOR
- NOT
- XOR
- XNOR

Implement Logic Gates with Perceptron

AND Gate

If the two inputs are TRUE (+1), the output of Perceptron is positive, which amounts to TRUE.

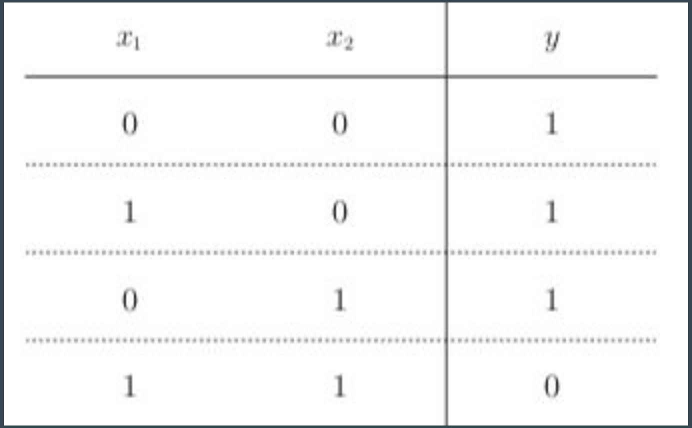


x_1	x_2	y
0	0	0
1	0	0
0	1	0
1	1	1

Implement Logic Gates with Perceptron

NAND Gate

If the two inputs are TRUE (+1), the output of Perceptron is negative, which amounts to TRUE.

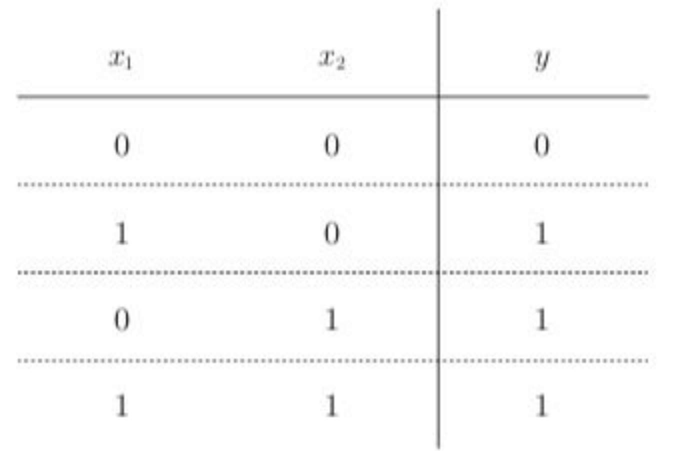


x_1	x_2	y
0	0	1
1	0	1
0	1	1
1	1	0

Implement Logic Gates with Perceptron

OR Gate

If either of the two inputs are TRUE (+1), the output of Perceptron is positive, which amounts to TRUE.

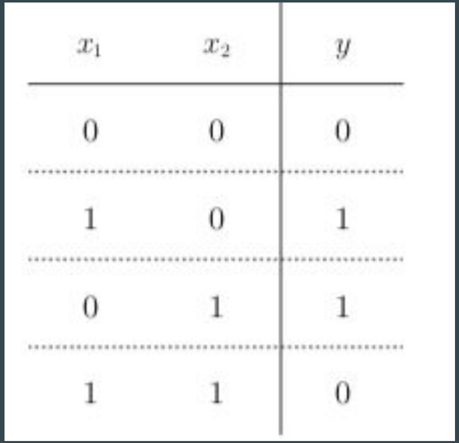


x_1	x_2	y
0	0	0
1	0	1
0	1	1
1	1	1

Implement Logic Gates with Perceptron

XOR Gate

The gate returns a TRUE as the output if and ONLY if one of the input states is true.



x_1	x_2	y
0	0	0
1	0	1
0	1	1
1	1	0

Implement Logic Gates with Perceptron

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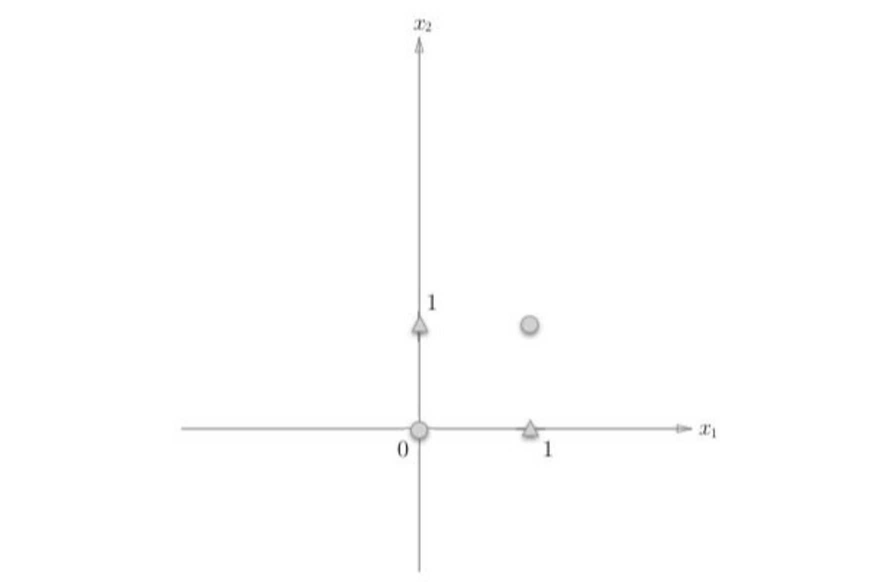

Implement Logic Gates with Perceptron

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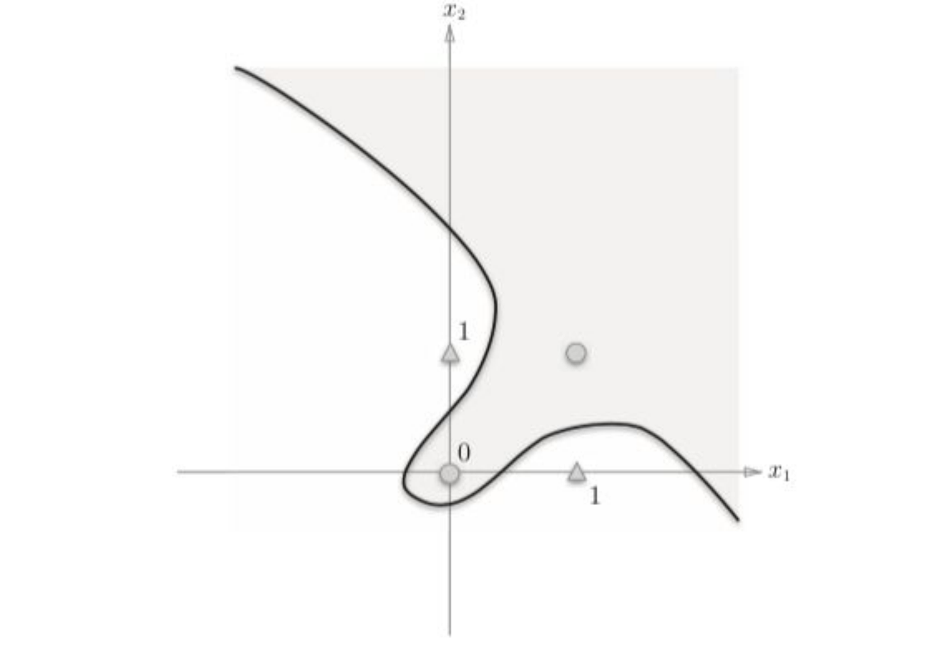
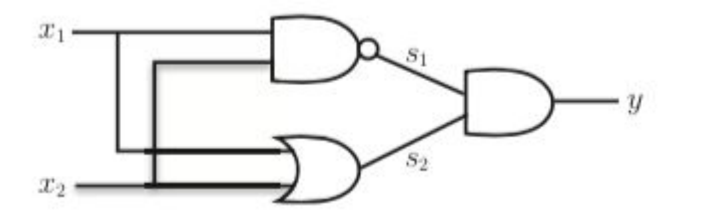
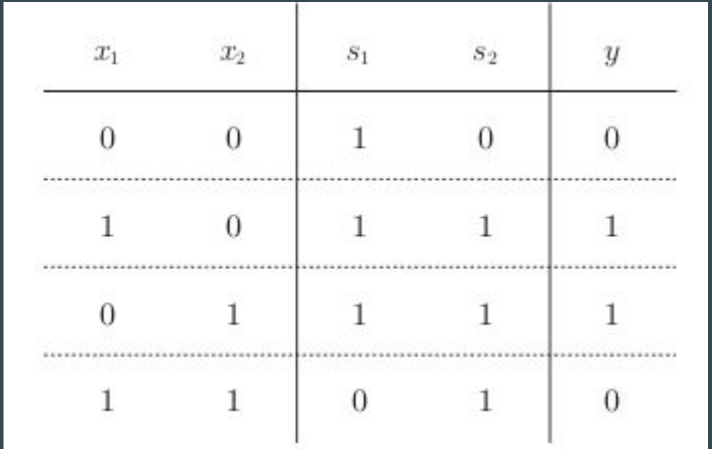
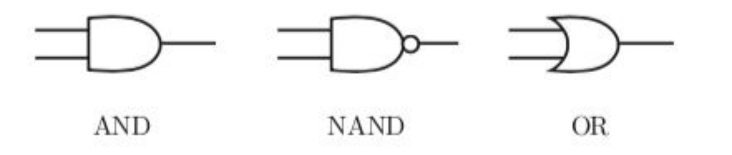


Multi-layered Perceptron

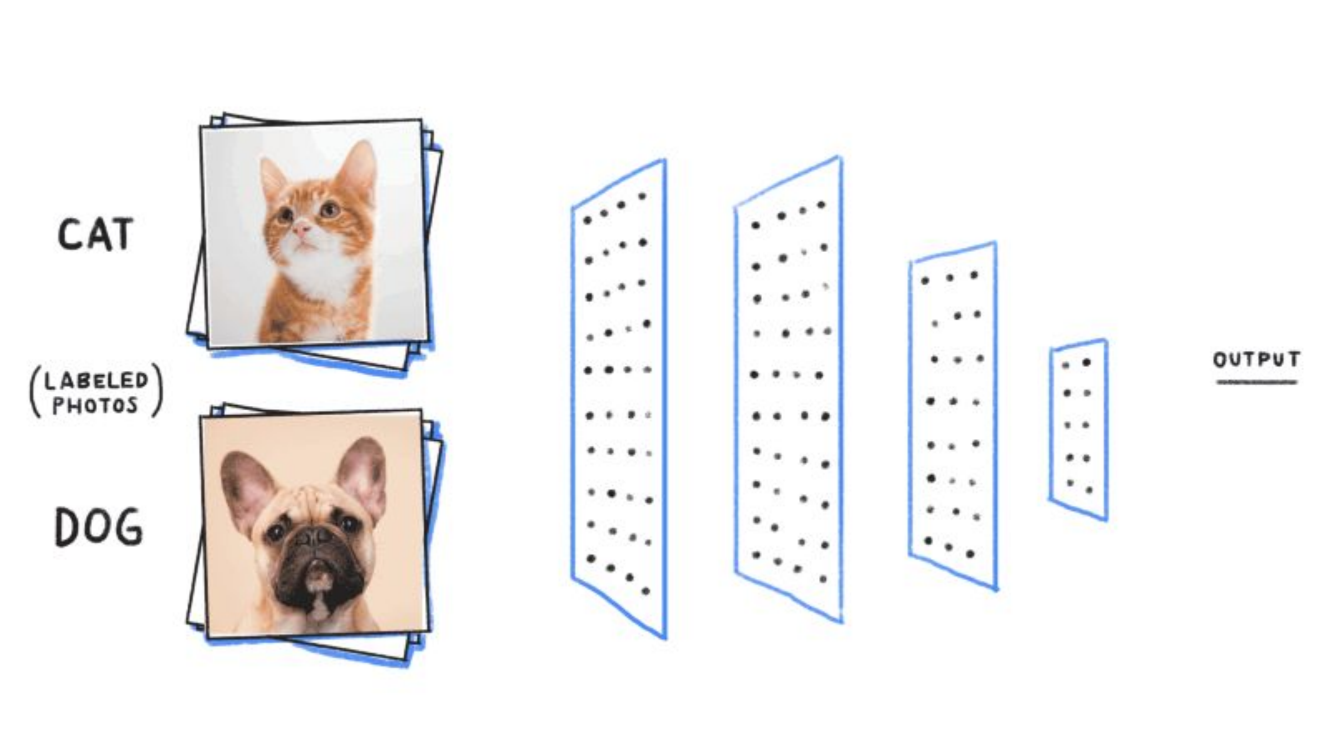




x_1	x_2	s_1	s_2	y
0	0	1	0	0
1	0	1	1	1
0	1	1	1	1
1	1	0	1	0



Neural Network



Summary

- An artificial neuron is a mathematical function conceived as a model of biological neurons, that is, a neural network.
- A Perceptron is a neural network unit that does certain computations to detect features or business intelligence in the input data. It is a function that maps its input “x,” which is multiplied by the learned weight coefficient, and generates an output value ”f(x).
- ”Perceptron Learning Rule states that the algorithm would automatically learn the optimal weight coefficients.
- Single layer Perceptrons can learn only linearly separable patterns.
- Multilayer Perceptron or feedforward neural network with two or more layers have the greater processing power and can process non-linear patterns as well.
- Perceptrons can implement Logic Gates like AND, OR, or XOR.

```python
for xs in [(0, 0), (1, 0), (0, 1), (1, 1)]:
    y = XOR(xs[0], xs[1])
    print(str(xs) + " -> " + str(y))
```

Ref.

- https://www.simplilearn.com/what-is-perceptron-tutorial
- https://github.com/oreilly-japan/deep-learning-from-scratch/tree/master/ch02
- https://github.com/oreilly-japan/deep-learning-from-scratch
- https://towardsdatascience.com/what-the-hell-is-perceptron-626217814f53