DRIVES

Development and Research on Innovative Vocational Education Skills

U3 DEEP LEARNING AND NEURAL NETWORKS

U3.E1 THE HUMAN BRAIN AND ITS COMPUTATIONALLY MODELLING

Artificial Intelligence Technician

March 2021, Version 1

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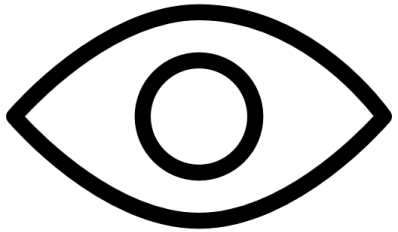
LEARNING OBJECTIVES

The student is able to

AIT.U3.E1.PC1	Know the structure of a biological human neuron as well as the functions of its constituents.
AIT.U3.E1.PC2	Understands the nature, purpose and applications of an artificial neuron.
AIT.U3.E1.PC3	Recognize and understand the similarities between a computational neuron and a human neuron
AIT.U3.E1.PC4	Know the most commonly used activation functions for artificial neurons.

Neurons or nerve cells, send and receive signals from your brain.

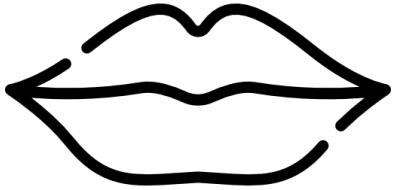
The nervous system controls all our senses:



Vision

Smell

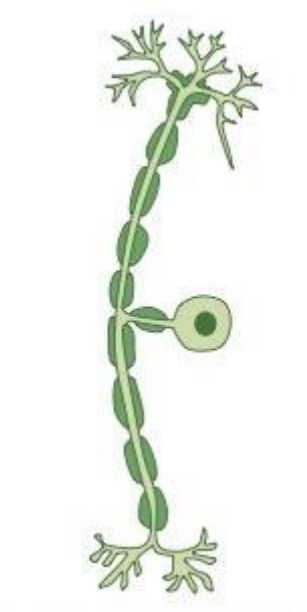
Hearing



Taste

In short, neurons are part of a system that deals with all the sensations that control our daily lives.

TYPES OF NEURONS

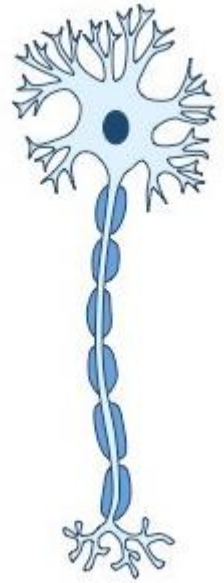


Sensory Neuron

They receive stimulus, which can come from the organism itself or the environment.

Motor Neurons

They are responsible for conducting nerve impulses to effector organs, such as muscles and glands.

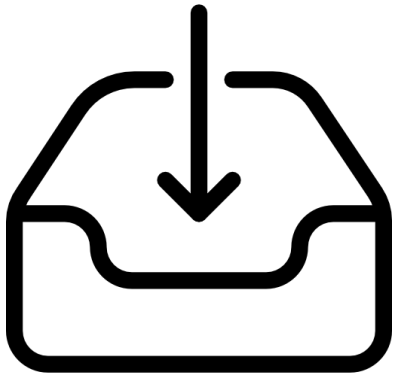


Interneurons

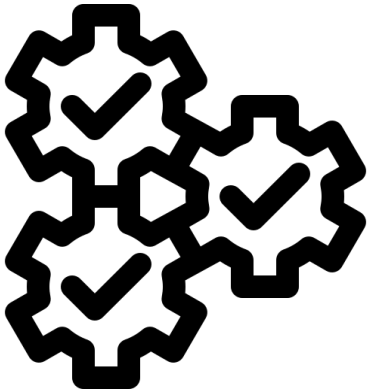
They guarantee the connection between neurons.

FUNCTIONS OF A NEURON

There are roles, one for the each classe of neurons. All of them have three basic functions:



1. Receive signals (or information).



2. Integrate input signals (to determine whether this information should be passed on or not).

3. Communicate signals to target cells (other neurons or muscles or glands).

These neuronal functions are reflected in the anatomy of the neuron.

COMPONENTS OF A NEURON

Dendrite

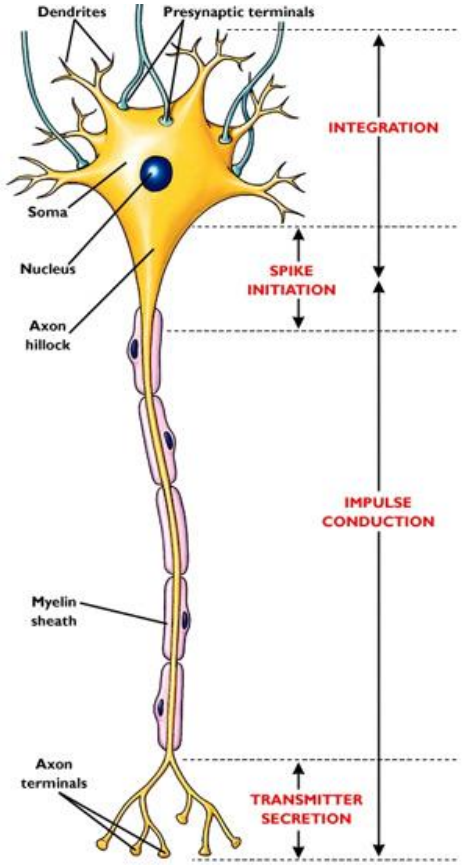
They are neuron extensions. They guarantee the reception of stimuli, leading the nervous impulse towards the cellular body.

Axon

Extension that guarantees the conduction of the nervous impulse. Each neuron has only one axon. Around the axon is an electrical insulation called myelin sheath. The sites where this sheath fails are called Ranvier's nodules.

Cellular Body

Place where the core is. Most of the cellular organelles are also located in the cellular body. In addition, it is from where the extensions of this cell originate.



The neuron collects signals from Dendrites, and the Soma cells sums up all the signals collected, and when the summation reaches the threshold the signal pass through the axon to the other neurons

ARTIFICIAL NEURON

The artificial neuron is a **simplified and simulated model** of the real neuron as well as its basic characteristics.

These characteristics are the adaptation and the representation of knowledge based on connections.

In 1943 MacCulloch & Pitts developed the first mathematical model of a neuron = node.

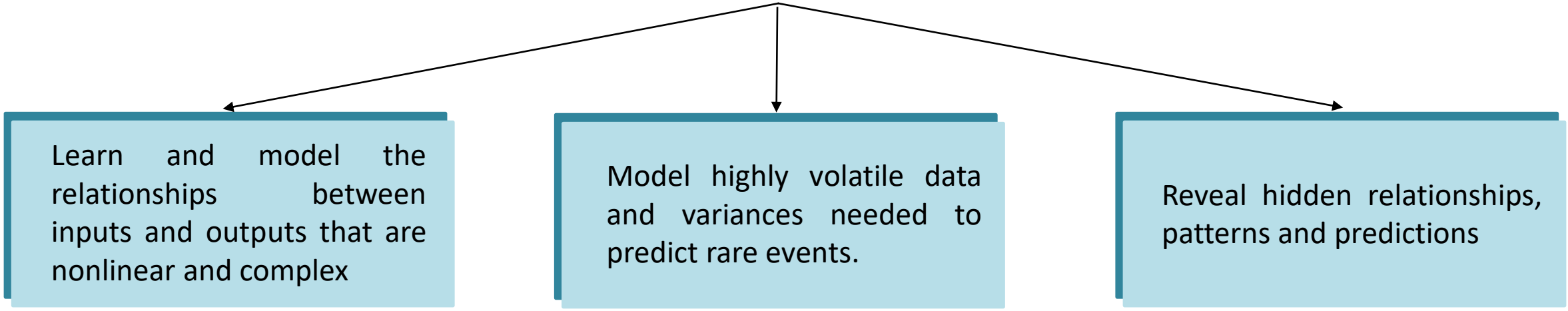
After some time, they realized that the combination of several neurons produces high computational power.

They associated the response of all or nothing (characteristic of a neuron) and realized that they only perform logical functions.

Concluding, they realized that a set of neurons can be represented by an artificial neuronal network

Neural networks, which consist of artificial neurons, have an excellent behavior for helping people with complex day-to-day problems

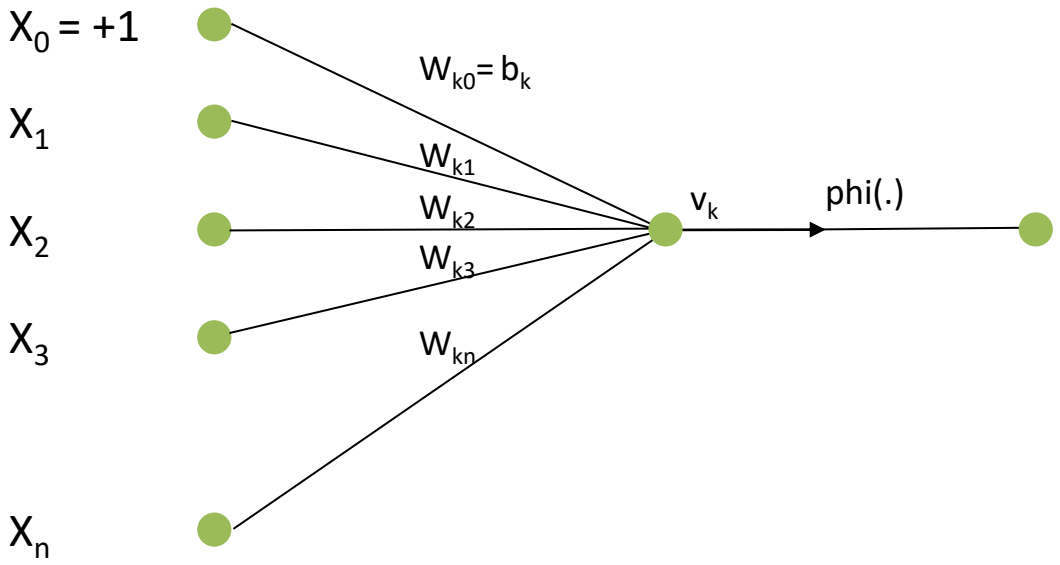
They are able to:



ARTIFICIAL NEURON: STRUCTURE

For a given artificial neuron k:

- $m + 1$ inputs
- signals x_0 through x_m
- weights w_{k0} through w_{km}
- *Transfer function phi*

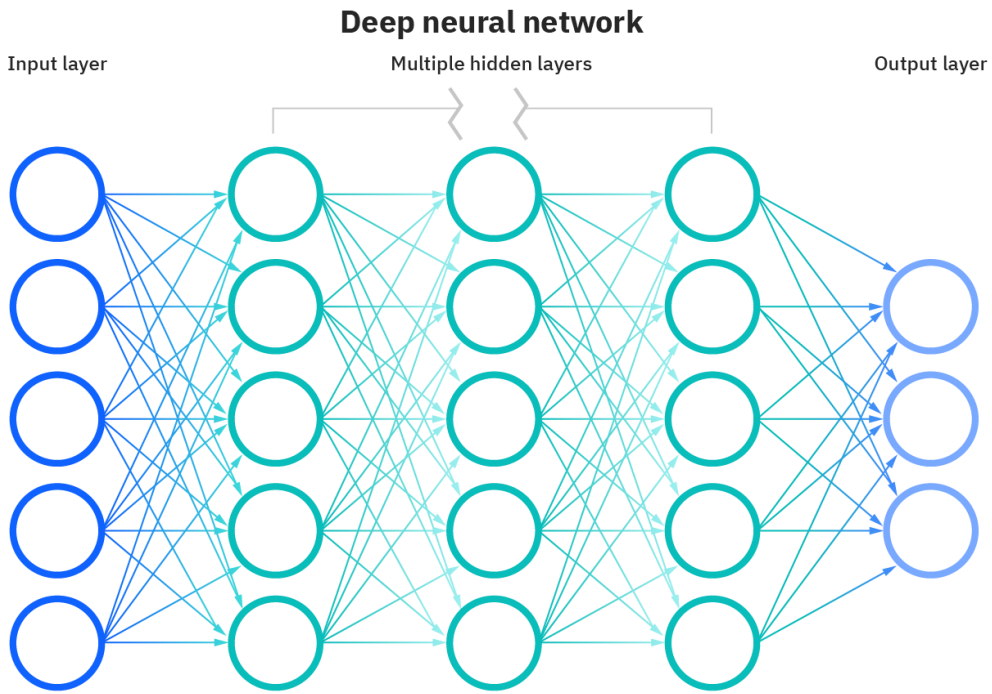


In the Neural Network, the neurons are arranged into multiple layers.

Input Layer : This layer accepts input features. It provides information from the outside world to the network, no computation is performed at this layer, nodes here just pass on the information(features) to the hidden layer.

Hidden Layer : Nodes of this layer are not exposed to the outer world, they are the part of the abstraction provided by any neural network. Hidden layer performs all sort of computation on the features entered through the input layer and transfer the result to the output layer.

Output Layer : This layer bring up the information learned by the network to the outer world.



ARTIFICIAL NEURON APPLICATIONS

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- Credit card fraud detection.
- Optimization of logistics for transportation networks.
- Character and voice recognition (Natural language processing).
- Medical and disease diagnosis.
- Targeted marketing.
- Financial predictions for stock prices, currency, options, futures, bankruptcy and bond ratings.
- Robotic control systems.
- Electrical load and energy demand forecasting.
- Process and quality control.
- Chemical compound identification.
- Ecosystem evaluation.
- Computer vision to interpret raw photos and videos (Medical Imaging, Robotics and Facial Recognition).

SIMILLARITIES BETWEEN ARTIFICIAL NEURON AND HUMAN NEURON

Both use electrical signals to send messages.

Both have a memory that can grow.

Both can adapt and learn.

Both need energy.

Both can do math and other logical tasks.

Both can change and be modified.

Both transmit information.

MAIN DIFFERENCES BETWEEN ARTIFICIAN NEURON AND HUMAN NEURON

Size
The human brain contains about 86 billion neurons and more than a 100 trillion synapses (connections). The number of "neurons" in artificial networks is much less than that.

Speed
Biological neurons can fire about 200 times a second on average. Signals travel at different speeds depending on the type of the nerve impulse, ranging from 0.61 m/s up to 119 m/s.

Power consumption
The human brain consumes about 20% of all the human body's energy. Our machines are way less efficient than biological systems.

Topology
All artificial layers compute one by one, instead of being part of a network that has nodes computing asynchronously.

Fault-tolerance
Biological neuron networks due to their topology are also fault-tolerant. Information is stored redundantly so minor failures will not result in memory loss. They don't have one "central" part.

Learning
We still do not understand how brains learn, or how redundant connections store and recall information

ACTIVATION FUNCTIONS

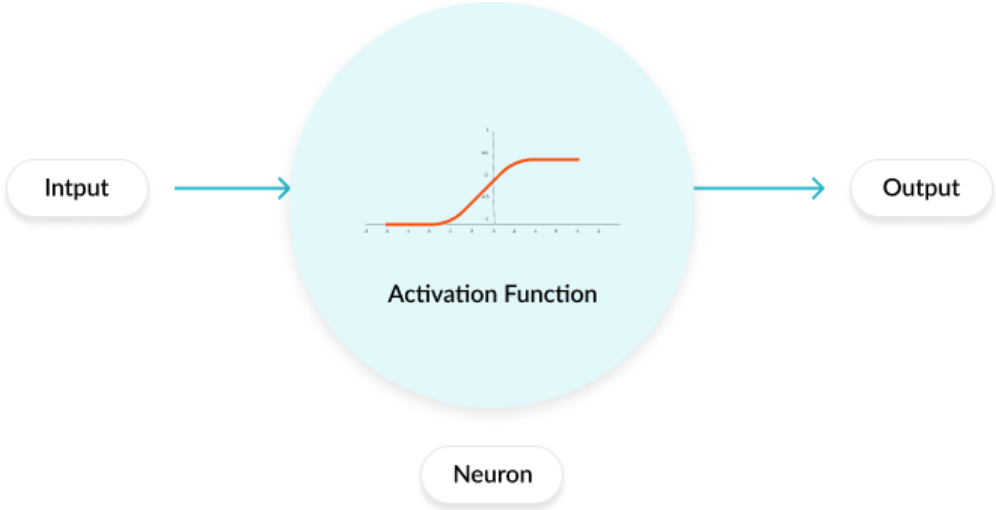
Activation functions are mathematical equations that determine the output of a neural network.

The function is attached to each neuron in the network, and determines whether it should be activated (“fired”) or not.

Activation functions also help normalize the output of each neuron to a range between 1 and 0 or between -1 and 1.

The Activation Functions can be basically divided into 2 types:

1. **Linear Activation Functions**
2. **Non-linear Activation Functions**



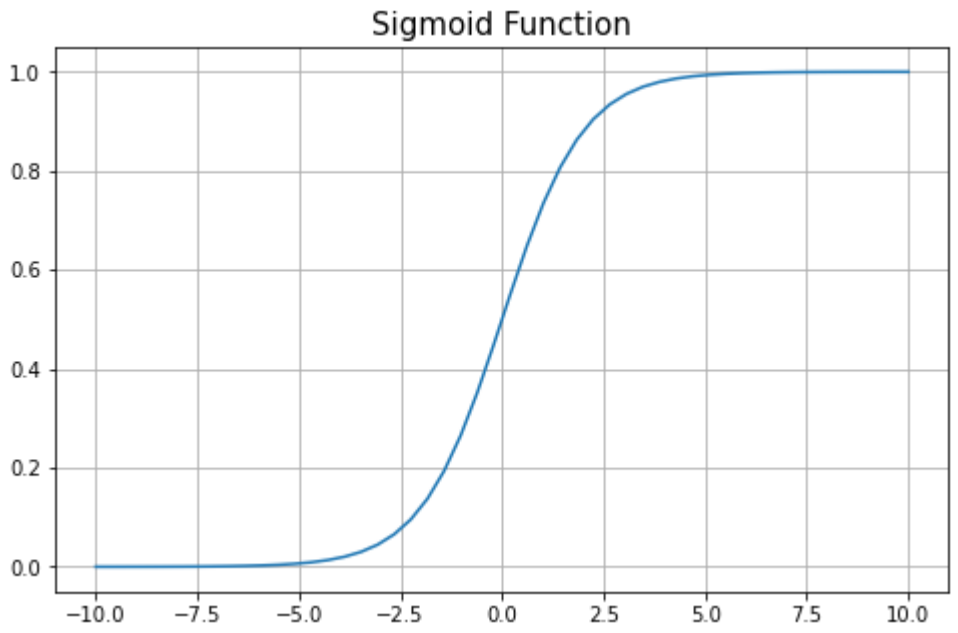
SIGMOID FUNCTION

It is very used because it exists between 0 and 1. Also because of that, it is the most used for models to predict probability.

$$Sigmoid\ Function = \frac{1}{1 + e^{-x}}$$

It is **Differentiable** and **Monotonic** → A function which is either entirely non-increasing or non-decreasing.

→ Change in y-axis w.r.t. change in x-axis.It is also known as slope.



⚠ **Downside:** The derivate tends towards zero as we move away from zero. The “learning” process of a neural network depends on the derivative because the weights are updated based on the gradient which basically is the derivate of a function.

TANH (HYPERBOLIC TANGENT)

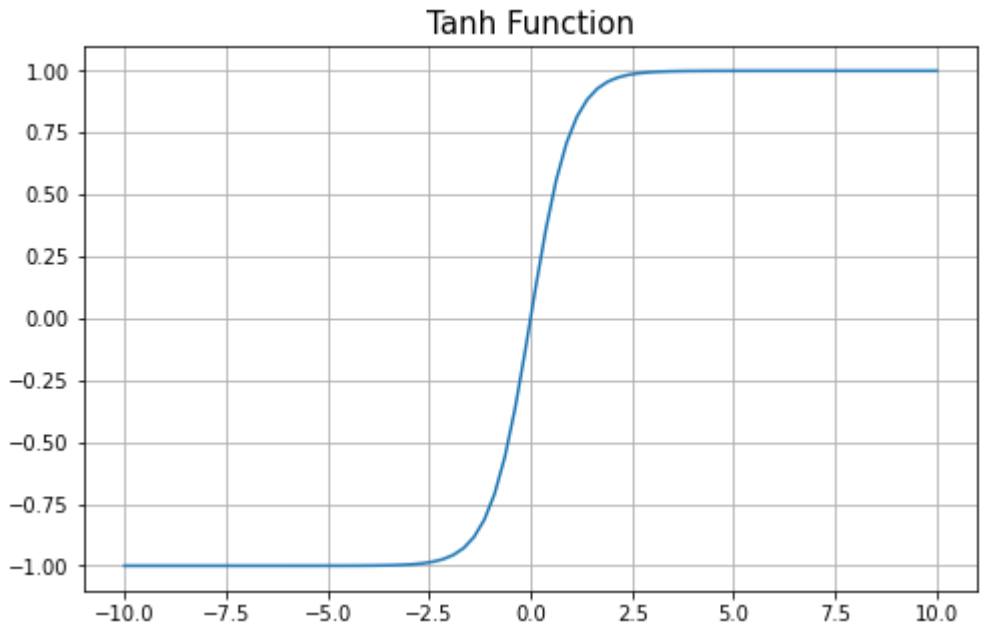
It is very similar to the sigmoid except that the output values are in the range of -1 to +1.

Tanh is said to be **zero centered.**

It is **Differentiable** and **Monotonic** (its derivative is not monotonic)

It is mainly used classification between two classes.

The difference between the sigmoid and tanh is that the gradients are not restricted to move in one direction for tanh.



Tanh is likely to converge faster

RELU (RECTIFIED LINEAR UNIT)

This activation function is only interested in the POSITIVE VALUES. The output range is from 0 to infinite.

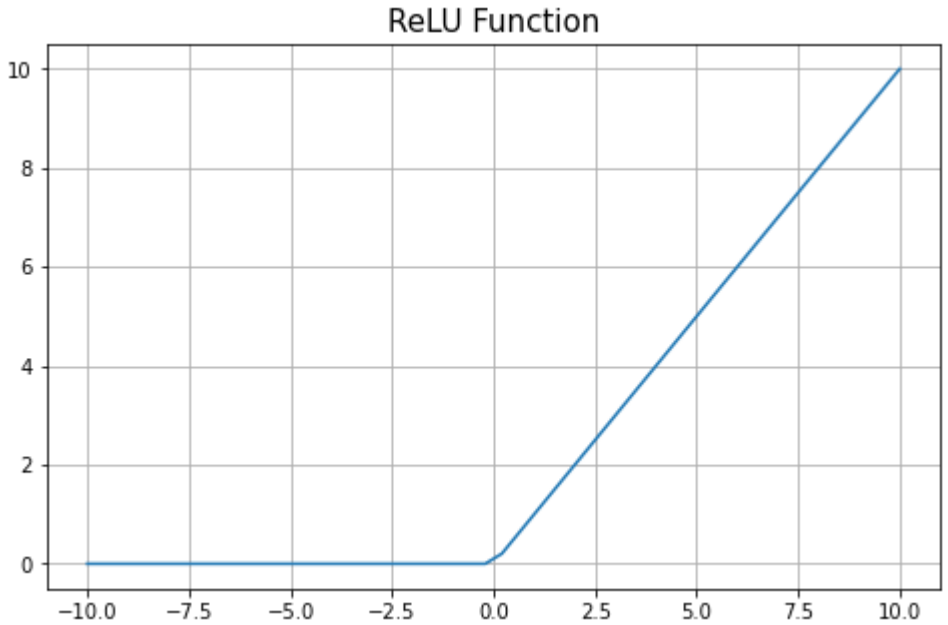
Keeps the input values greater than 0 as is. All the input values less than zero become 0.

The function and its derivative **both are monotonic**.

It is used in almost all the convolutional neural networks or deep learning.

Applying a ReLU function to the output of a neuron, all the values returned become 0

ReLU allows cancelling, but also activate, some of the neurons.



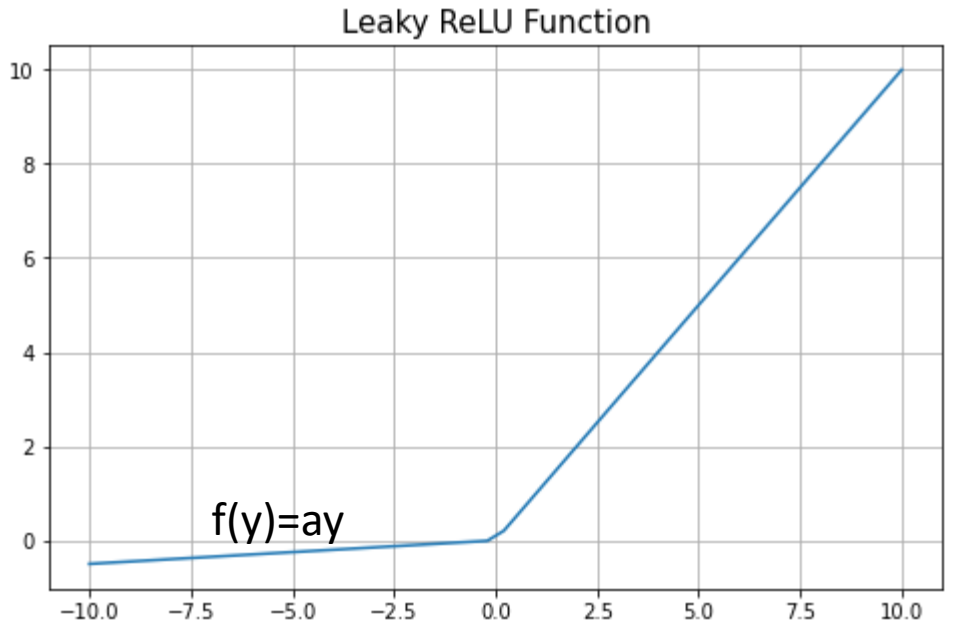
LEAKY RELU

Leaky ReLU outputs a small value for negative inputs. The output values can be from –infinite to infinite.

The leak helps to increase the range of the ReLU function. Usually, the value of a is 0.01 or so.

When **a is not 0.01** then it is called **Randomized ReLU**.

Both Leaky and Randomized ReLU functions are monotonic as well as their derivates.



In general, the desired properties of an activation function are:

Computationally inexpensive

Zero centered

Not causing vanishing gradient problem

Differentiable.
The derivative of an activation function needs to carry information about the input values because weights are updated based on the gradients.

- Neurons send and receive signals from your brain.
- There are 3 types of neurons: Sensory Neurons, Motor Neurons and Interneurons. Each one has specific functions like receive, integrate and communicate signals.
- The artificial neuron is a **simplified and simulated model** of the real neuron as well as its basic characteristics.
- In a Neural Network, the neurons are arranged into multiple layers (1 Input Layer, n Hidden Layers, 1 Output Layer).
- There are manu simmilarities between the biological neurons and the artificial ones(both use electrical signals to send messages, have memory that can grow and can adapt and learn). But there are also many differences like the limited size of the artificial neural network, the speed or even the fault tollerance that neural networks can't replicate.
- The output of a neural network is determined by activation function. The most used are: Sigmoid Function, Tanh Function, ReLu and Leaky ReLu.
- **The optimal activation function should be zero centered, use low computational resources, not caus vanishing gradient problem and be differenciable**

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DRIVES project is project under **The Blueprint for Sectoral Cooperation on Skills in Automotive Sector**, as part of New Skills Agenda.

The aim of the Blueprint is **to support an overall sectoral strategy and to develop concrete actions to address short and medium term skills needs.**

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