Artificial Neural Network(ANN)

The human brain is a complex connected neural network where different regions of the brain are responsible for different jobs, and these regions are machines of the brain that receive signals and processes it to take necessary action.

Our brain is made up of a cluster of small connected units called neurons, which send electrical signals to one another. The long-term knowledge is represented by the strength of the connections between neurons.

Ex:

When we see objects, light travels through the retina and the visual information gets converted to electrical signals, and further on the electric signal passes through the hierarchy of connected neurons of different regions within the brain in a few milliseconds to decode signals/information.

Description	Example
View point variation : Same object can have different orientation.	
Scale and illumination variation: Variation in object's size and the level of illumination on pixel level can vary.	
Deformation/twist and intra-class variation: Non-rigid bodies can be deformed in great ways and there can be different types of objects with varying appearance within a class.	
Blockage: Only small portion of object in interest can be visible.	

	
Background clutter : Objects can blend into their environment, which will make it hard to identify.	

Black Box Methods -Neural Networks (ANN)

Two of the most powerful machine learning algorithms applied across many domains are the ANNs and SVMs

Neural networks use concepts borrowed from an understanding of humanbrains in order to model arbitrary functions.

Support Vector Machines(SVM) use multidimensional surfaces to define the relationship between features and outcomes.

An **Artificial Neural Network** (**ANN**) models the relationship between a set of input signals and an output signal using a model derived from our understanding of how a biological brain responds to stimuli from sensory inputs.

ANNs are currently applied to:

- ✓ Speech and handwriting recognition programs like those used by voicemail transcription services and postal mail sorting machines
- ✓ The automation of smart devices like an office building's environmental controls or self-driving cars and self-piloting drones
- ✓ Sophisticated models of weather and climate patterns, tensile strength, fluid dynamics, and many other scientific, social, or economic phenomena

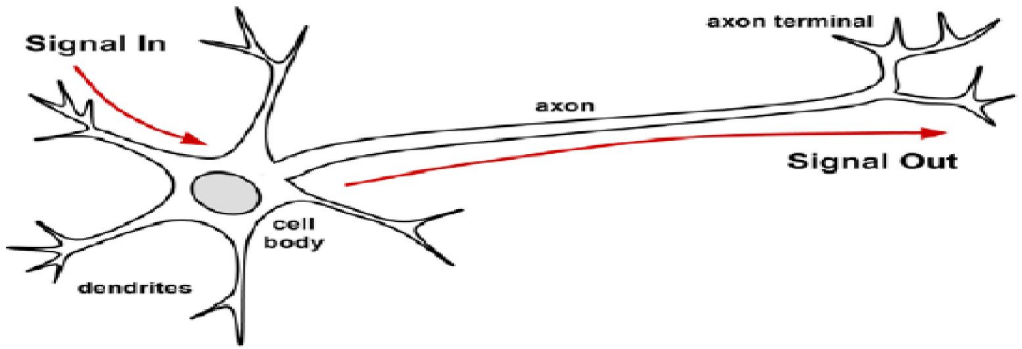
ANNs are versatile learners that can be applied to nearly any learning task: classification, numeric prediction, and even unsupervised pattern recognition.

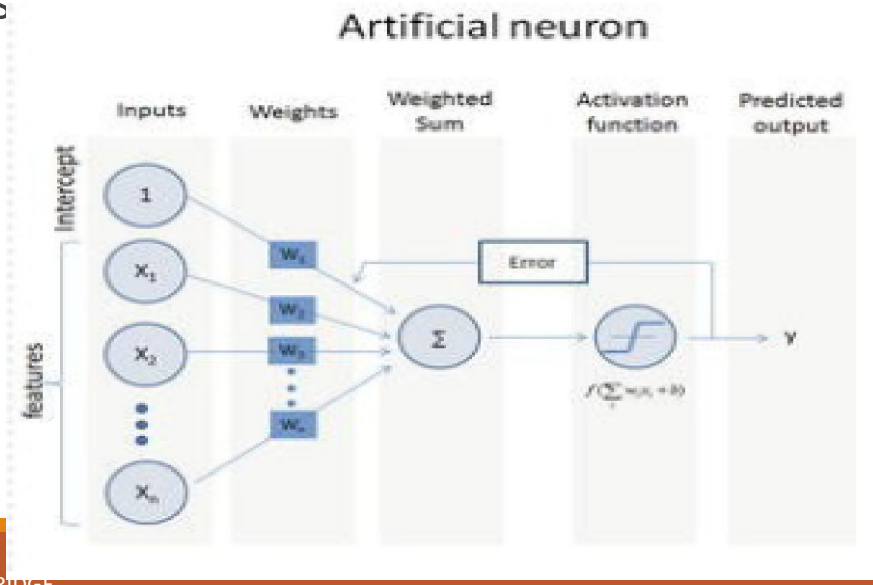
Understanding the artificial neurons

In the biological neural functions, incoming signals are received by the cell's dendrites through a biochemical process that weighs the impulse based on relative frequency.

As the cell body begins to accumulate incoming signals, a threshold is reached at which the cell fires and output signal is transmitted via an electrochemical process down the axon.

At the axon's terminal, electric signal is again processed as [illegible] uring neurons across a tiny gap known as '*synapse*'.





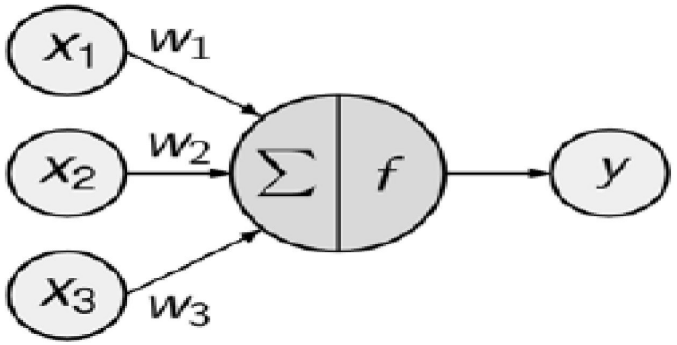
Understanding the Artificial Neuron

Perceptron as an artificial neuron that is the basic building block of the artificial neural network.

The model of a single artificial neuron can be understood in terms very similar to the biological model.

A directed network diagram defines a relationship between the input signals received by the dendrites (*x* variables) and the output signal (*y* variable).

Just as with the biological neuron, each dendrite's signal is weighted (*w* values) according to its importance—ignore for now how these weights are determined. The input signals are summed by the cell body and the signal is passed on according to an **activation function** denoted by *f*.



$$y(x) = f\left(\sum_{i=1}^{n} w_i x_i\right)$$

Neural networks use neurons defined like above as building blocks to construct complex models of data.

An **activation function**, which transforms a neuron's net input signal into a single output signal to be broadcasted further in the network

A **network topology** (or architecture), which describes the number of neurons in the model as well as the number of layers and manner in which

they are connected

The **training algorithm** that specifies how connection weights are set in order to inhibit or excite neurons in proportion to the input signal

Activation function is used by artificial neuron to process the information and pass it through the network. It sums the total input signal and determines whether the total meets the firing threshold. If it so, the neuron passes the signal.

In ANN terms, this is known as **threshold activation function.**

Network topology deals with the learning capacity of a neural network. Topology refers to the patterns and structure of interconnected neurons.

1. The number of layers
2. Whether information in the network is allowed to travel backward
3. The number of nodes within each layer of the network

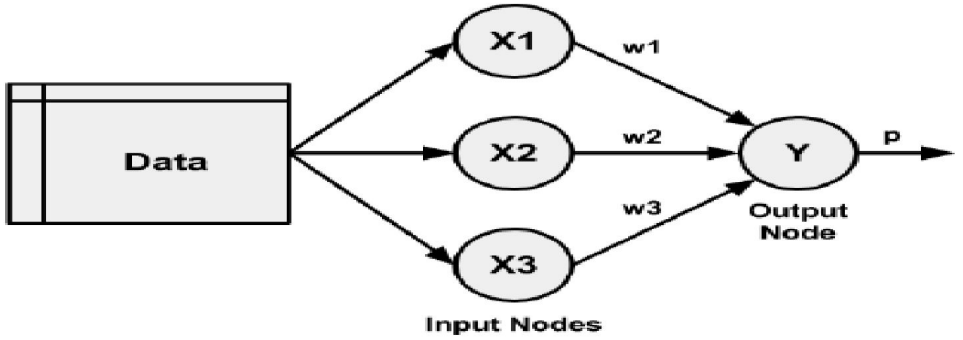
Number of Layers

Artificial neurons might be based in different positions in a network.

A set of neurons called ***Input Nodes*** receive unprocessed signals directly from input data.

Each input node is responsible for processing a single feature in the dataset and the feature's value will be transformed by the node's activation function.

Signals resulting from input node are received by the ***Output Node*** which uses its own activation function to generate a final prediction.



Input and output nodes are arranged in groups known as **layers**.

Input nodes process the incoming data exactly as received, the network has only one set of connection weights(w1,w2,w3) i.e. single-layer network.

Single layer network can be used for pattern classification.

Multi layer network adds one or more hidden layers that process signals from input nodes prior to reaching output node.

Direction of information travel

Networks in which input signal is fed continuously in one direction from connection-to-connection until reaching the output layer are called **feedforward networks**.

A **recurrent network(or feedback network)** allows signals to travel in both directions using loops allowing complex patterns to be learned.

Ex: Stock market prediction, speech recognition, weather forecasting.

The **Multilayer Perceptron** (**MLP**) is the de facto standard ANN topology.

The number of input nodes is predetermined by the number of features in the input data.

The number of output nodes is predetermined by the number of outcomes to be modelled or the number of class levels in the outcome.

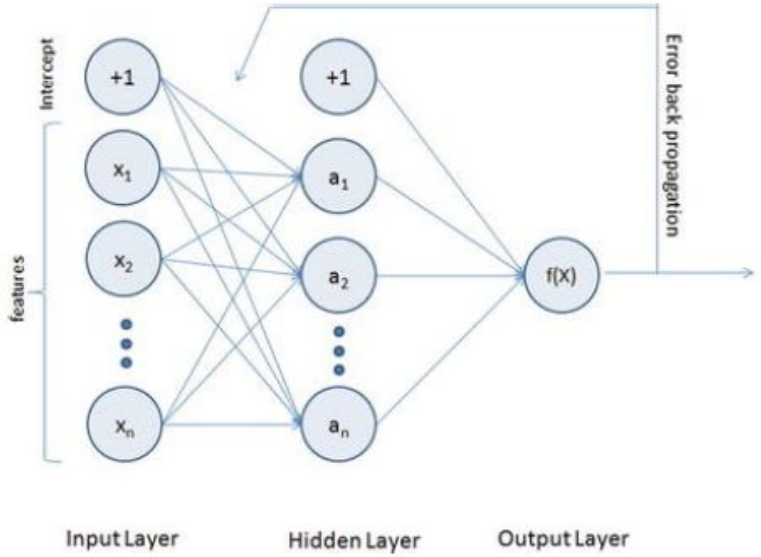
The number of hidden nodes is left to the user to decide prior to training the model.

Multilayer Perceptron

To address the drawback of single perceptrons, multilayer perceptrons were proposed; also commonly known as a feedforward neural network.

It is a composition of multiple perceptrons connected in different ways and operating on distinctive activation functions to enable improved learning mechanisms.

The training sample propagates forward through the network and the output error is back propagated and the error is minimized using the gradient descent method, which will calculate a loss function for all the weights in the network.



The activation function for a simple one-level hidden layer of a multilayer perceptron can be given by:

$$f(x) = g\left(\sum_{j=0}^{M} W_{kj}^{(2)} g\left(\sum_{i=0}^{d} W_{ji}^{(1)} x_i\right)\right)$$, where x_i is the input and $W_{ji}^{(1)}$ is the input layer weights and $W_{kj}^{(2)}$ is the weight of hidden layer.

A multilayered neural network can have many hidden layers, where the network holds its internal abstract representation of the training sample. The upper layers will be building new abstractions on top of the previous layers. So having more hidden layers for a complex dataset will help the neural network to learn better.
