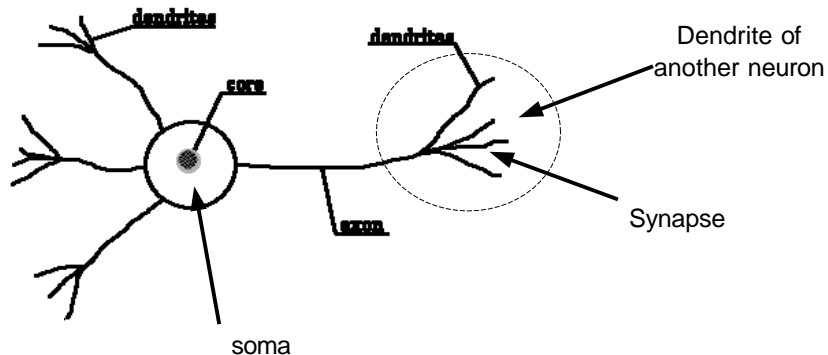# Artificial Neural Network : Introduction

Biological nervous system

- Biological nervous system is the most important part of many living things, in particular, human beings.

- There is a part called **brain** at the center of human nervous system.

- In fact, any biological nervous system consists of a large number of interconnected processing units called **neurons**.

- Each neuron is approximately $10\mu m$ long and they can operate in parallel.

- Typically, a human brain consists of approximately 10^{11} neurons communicating with each other with the help of electrical impulses.

Gray matter

Cerebellum

Spinal Cord
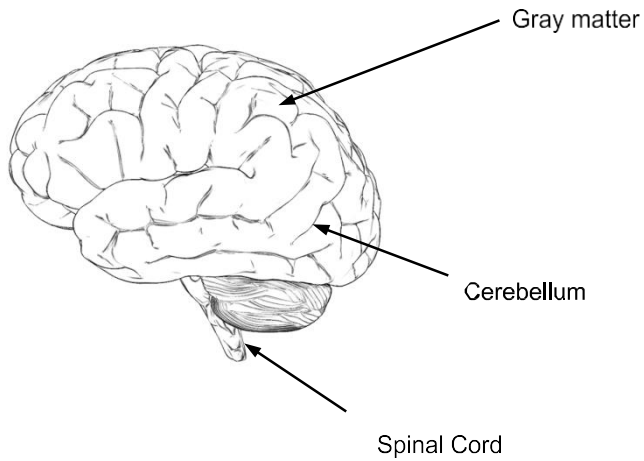
Neuron: Basic unit of nervous system

dendrites

core

dendrites

Dendrite of another neuron

Synapse

axon
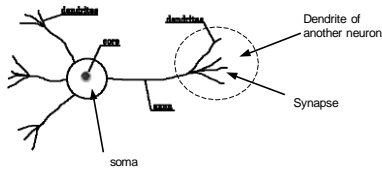
soma

Neuron and its working

Figure shows a schematic of a biological neuron. There are different parts in it : dendrite, soma, axon and synapse.

- **Dendrite** : A bush of very thin fibre.

- **Axon** : A long cylindrical fibre.

- **Soma** : It is also called a cell body, and just like as a nucleus of cell.

- **Synapse** : It is a junction where axon makes contact with the dendrites of neighboring dendrites.
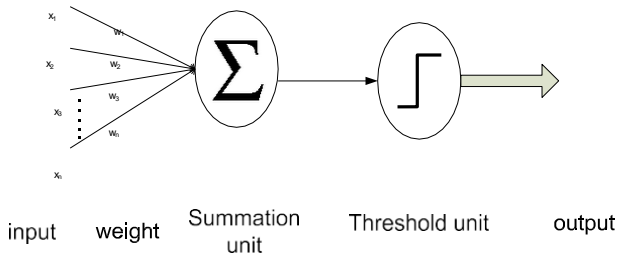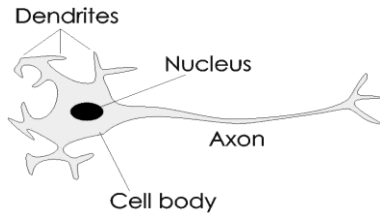
Neuron and its working

- There is a chemical in each neuron called neurotransmitter.
- A signal (also called sense) is transmitted across neurons by this chemical.
- That is, all inputs from other neuron arrive to a neurons through dendrites.
- These signals are accumulated at the synapse of the neuron and then serve as the output to be transmitted through the neuron.
- An action may produce an electrical impulse, which usually lasts for about a millisecond.
- Note that this pulse generated due to an incoming signal and all signal may not produce pulses in axon unless it crosses a **threshold value**.
- Also, note that an action signal in axon of a neuron is commutative signals arrive at dendrites which summed up at soma.

Glial cells

Synapse

Dendrite

Nucleus

Axon

Myelin sheath
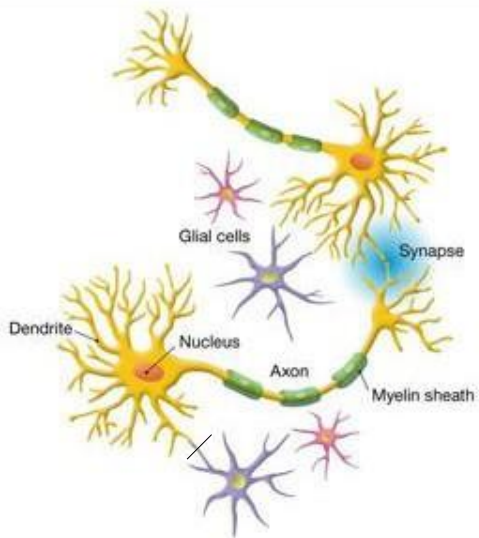
Artificial neural network

- In fact, the human brain is a highly complex structure viewed as a massive, highly interconnected network of simple processing elements called **neurons**.

- Artificial neural networks (ANNs) or simply we refer it as neural network (NNs), which are simplified models (i.e. imitations) of the biological nervous system, and obviously, therefore, have been motivated by the kind of computing performed by the human brain.

- The behavior of a biolgical neural network can be captured by a simple model called artificial neural network.

Dendrites

Nucleus

Axon

Cell body

x_1 w_1

x_2 w_2

x_3 w_3

         w_n

x_n

Σ

input   weight   Summation   Threshold unit   output
   unit

Artificial neural network

We may note that a neutron is a part of an interconnected network of nervous system and serves the following.

- Compute input signals
- Transportation of signals (at a very high speed)
- Storage of information
- Perception, automatic training and learning

We also can see the analogy between the biological neuron and artificial neuron. Truly, every component of the model (i.e. artificial neuron) bears a direct analogy to that of a biological neuron. It is this model which forms the basis of neural network (i.e. artificial neural network).

Artificial neural network

input   weight   Summation   Threshold unit   output
                   unit
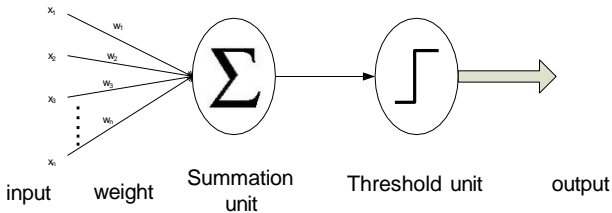
- Here, $x_1, x_2, \cdots, x_n$ are the n inputs to the artificial neuron.

- $w_1, w_2, \cdots, w_n$ are weights attached to the input links.
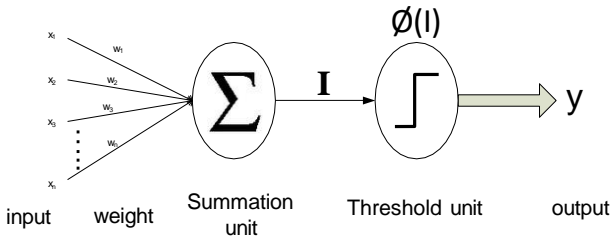
Artificial neural network

- Note that, a biological neuron receives all inputs through the dendrites, sums them and produces an output if the sum is greater than a threshold value.

- The input signals are passed on to the cell body through the synapse, which may accelerate or retard an arriving signal.

- It is this acceleration or retardation of the input signals that is modeled by the **weights**.

- An effective synapse, which transmits a stronger signal will have a correspondingly larger weights while a weak synapse will have smaller weights.

- Thus, weights here are multiplicative factors of the inputs to account for the strength of the synapse.

Artificial neural network

- Hence, the total input say I received by the soma of the artificial neuron is

$$I = w_1 x_1 + w_2 x_2 + \cdots + w_n x_n = \sum_{i=1}^{n} w_i x_i$$

- To generate the final output y, the sum is passed to a filter φ called transfer function, which releases the output.
- That is, $y = \varphi(I)$

Artificial neural network

- A very commonly known transfer function is the **thresholding function**.

- In this thresholding function, sum (i.e. I) is compared with a threshold value ϑ.

- If the value of I is greater than ϑ, then the output is 1 else it is 0 (this is just like a simple linear filter).

- In other words,
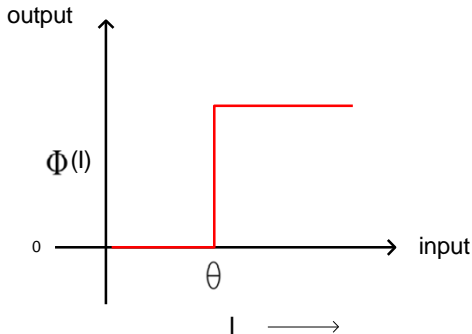
$$y = \varphi\left(\sum_{i=1}^{n} w_i x_i - \vartheta \right)$$

where

$$\varphi(I) = \begin{array}{ll} 1 & \text{, if } I > \vartheta \\ 0 & \text{, if } I \le \vartheta \end{array}$$
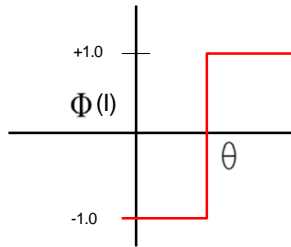
Such a Φ is called step function (also known as Heaviside function).

Artificial neural network

Following figures illustrates two simple thresholding functions.

(a) Hard-limit transfer function

(b) Signum transfer function

Transformation functions

- **Hard-limit transfer function** : The transformation we have just discussed is called hard-limit transfer function. It is generally used in perception neuron.

  In other words,

  $$\varphi(I) = \begin{cases} 1 & \text{, if } I > \vartheta \\ 0 & \text{, if } I \le \vartheta \end{cases}$$

- **Linear transfer function :** The output of the transfer function is made equal to its input (normalized) and its lies in the range of -1.0 to $+1.0$. It is also known as Signum or Quantizer function and it defined as

  $$\varphi(I) = \begin{cases} +1 & \text{, if } I > \vartheta \\ -1 & \text{, if } I \le \vartheta \end{cases}$$

Other transformation functions

- **Sigmoid transfer function** : This function is a continuous function that varies gradually between the asymptotic values 0 and 1 (called log-sigmoid) or -1 and +1 (called Tan-sigmoid) threshold function and is given by

$$\varphi(I) = \frac{1}{1 + e^{-\alpha I}} \text{ [log-Sigmoid]}$$

$$\varphi(I) = tanh(I) = \frac{e^{\alpha I} - e^{-\alpha I}}{e^{\alpha I} + e^{-\alpha I}} \text{ [tan-Sigmoid]}$$

Here, α is the coefficient of transfer function.

Advantages of ANN

- ANNs exhibits mapping capabilities, that is, they can map input patterns to their associated output pattern.

- The ANNs learn by examples. Thus, an ANN architecture can be trained with known example of a problem before they are tested for their inference capabilities on unknown instance of the problem. In other words, they can identify new objects previous untrained.

- The ANNs posses the capability to generalize. This is the power to apply in application where exact mathematical model to problem are not possible.

Advantages of ANN

- The ANNs are robust system and fault tolerant. They can therefore, recall full patterns from incomplete, partial or noisy patterns.

- The ANNS can process information in parallel, at high speed and in a distributed manner. Thus a massively parallel distributed processing system made up of highly interconnected (artificial) neural computing elements having ability to learn and acquire knowledge is possible.