

# Module 12

## Machine Learning

Version 1 CSE IIT, Kharagpur

# Lesson 37

## Learning and Neural Networks - I

## 12.4 Neural Networks

Artificial neural networks are among the most powerful learning models. They have the versatility to approximate a wide range of complex functions representing multi-dimensional input-output maps. Neural networks also have inherent adaptability, and can perform robustly even in noisy environments.

An Artificial Neural Network (ANN) is an information processing paradigm that is inspired by the way biological nervous systems, such as the brain, process information. The key element of this paradigm is the novel structure of the information processing system. It is composed of a large number of highly interconnected simple processing elements (neurons) working in unison to solve specific problems. ANNs, like people, learn by example. An ANN is configured for a specific application, such as pattern recognition or data classification, through a learning process. Learning in biological systems involves adjustments to the synaptic connections that exist between the neurons. This is true of ANNs as well. ANNs can process information at a great speed owing to their highly massive parallelism.

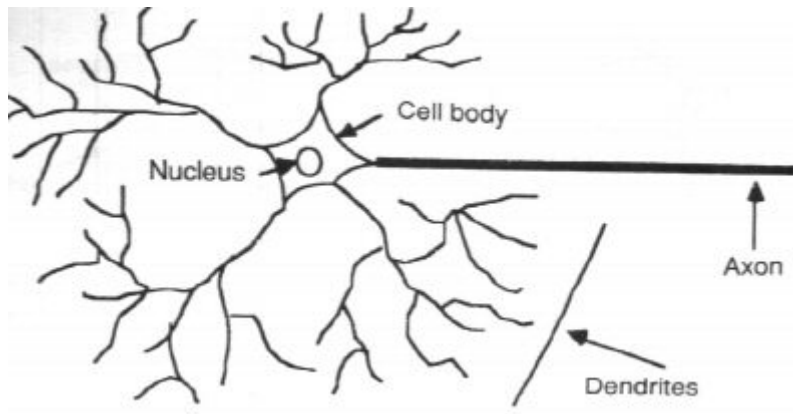
Neural networks, with their remarkable ability to derive meaning from complicated or imprecise data, can be used to extract patterns and detect trends that are too complex to be noticed by either humans or other computer techniques. A trained neural network can be thought of as an "expert" in the category of information it has been given to analyse. This expert can then be used to provide projections given new situations of interest and answer "what if" questions. Other advantages include:

1. Adaptive learning: An ability to learn how to do tasks based on the data given for training or initial experience.
2. Self-Organisation: An ANN can create its own organisation or representation of the information it receives during learning time.
3. Real Time Operation: ANN computations may be carried out in parallel, and special hardware devices are being designed and manufactured which take advantage of this capability.
4. Fault Tolerance via Redundant Information Coding: Partial destruction of a network leads to the corresponding degradation of performance. However, some network capabilities may be retained even with major network damage.

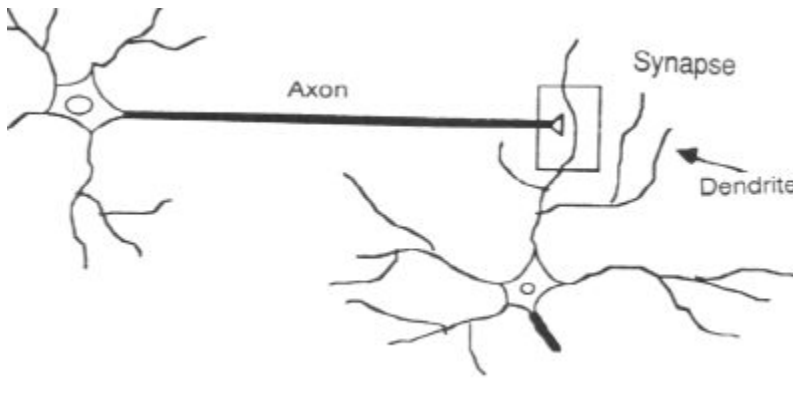
### 12.4.1 Biological Neural Networks

Much is still unknown about how the brain trains itself to process information, so theories abound. In the human brain, a typical neuron collects signals from others through a host of fine structures called *dendrites*. The neuron sends out spikes of electrical activity through a long, thin strand known as an *axon*, which splits into thousands of branches. At the end of each branch, a structure called a *synapse* converts the activity from the axon into electrical effects that inhibit or excite activity from the axon into electrical effects that inhibit or excite activity in the connected neurones. When a neuron receives

excitatory input that is sufficiently large compared with its inhibitory input, it sends a spike of electrical activity down its axon. Learning occurs by changing the effectiveness of the synapses so that the influence of one neuron on another changes.



**Components of a Biological Neuron**



**The Synapse**

### 12.4.2 Artificial Neural Networks

Artificial neural networks are represented by a set of nodes, often arranged in layers, and a set of weighted directed links connecting them. The nodes are equivalent to neurons, while the links denote synapses. The nodes are the information processing units and the links acts as communicating media.

There are a wide variety of networks depending on the nature of information processing carried out at individual nodes, the topology of the links, and the algorithm for adaptation of link weights. Some of the popular among them include:

**Perceptron:** This consists of a single neuron with multiple inputs and a single output. It has restricted information processing capability. The information processing is done through a transfer function which is either linear or non-linear.

**Multi-layered Perceptron (MLP):** It has a layered architecture consisting of input, hidden and output layers. Each layer consists of a number of perceptrons. The output of each layer is transmitted to the input of nodes in other layers through weighted links. Usually, this transmission is done only to nodes of the next layer, leading to what are known as feed forward networks. MLPs were proposed to extend the limited information processing capabilities of simple perceptrons, and are highly versatile in terms of their approximation ability. Training or weight adaptation is done in MLPs using supervised backpropagation learning.

**Recurrent Neural Networks:** RNN topology involves backward links from output to the input and hidden layers. The notion of time is encoded in the RNN information processing scheme. They are thus used in applications like speech processing where inputs are time sequences data.

**Self-Organizing Maps:** SOMs or Kohonen networks have a grid topology, with unequal grid weights. The topology of the grid provides a low dimensional visualization of the data distribution. These are thus used in applications which typically involve organization and human browsing of a large volume of data. Learning is performed using a winner take all strategy in an unsupervised mode.

In this module we will discuss perceptrons and multi layered perceptrons.