INTELLIGENT SYSTEMS

PART 3 :

Artificial Neural Networks (ANN)

AI Systems

- The goal of AI is the development of various paradigms or algorithms that require machines to perform cognitive tasks at which humans are currently better (Sage, 1990).
- An AI system must be capable of:
  - Storing or learning knowledge
  - Applying learnt knowledge
  - Acquiring new knowledge
- An Artificial Neural Network (ANN) is an AI system as it is able to (depending on the architecture) accomplish all 3 capabilities.

Introduction to ANN

- An ANN is a system used to solve a problem or give outputs for a set of given inputs.
- The concept of ANN is inspired by the functioning of human brain.
- There are many types of ANN architecture that can be developed to produce an ANN system for solving a task.
- The key to developing an ANN is based on either
  - Supervised learning, or
  - Unsupervised learning

  or a combination of both.

Foundation of ANN

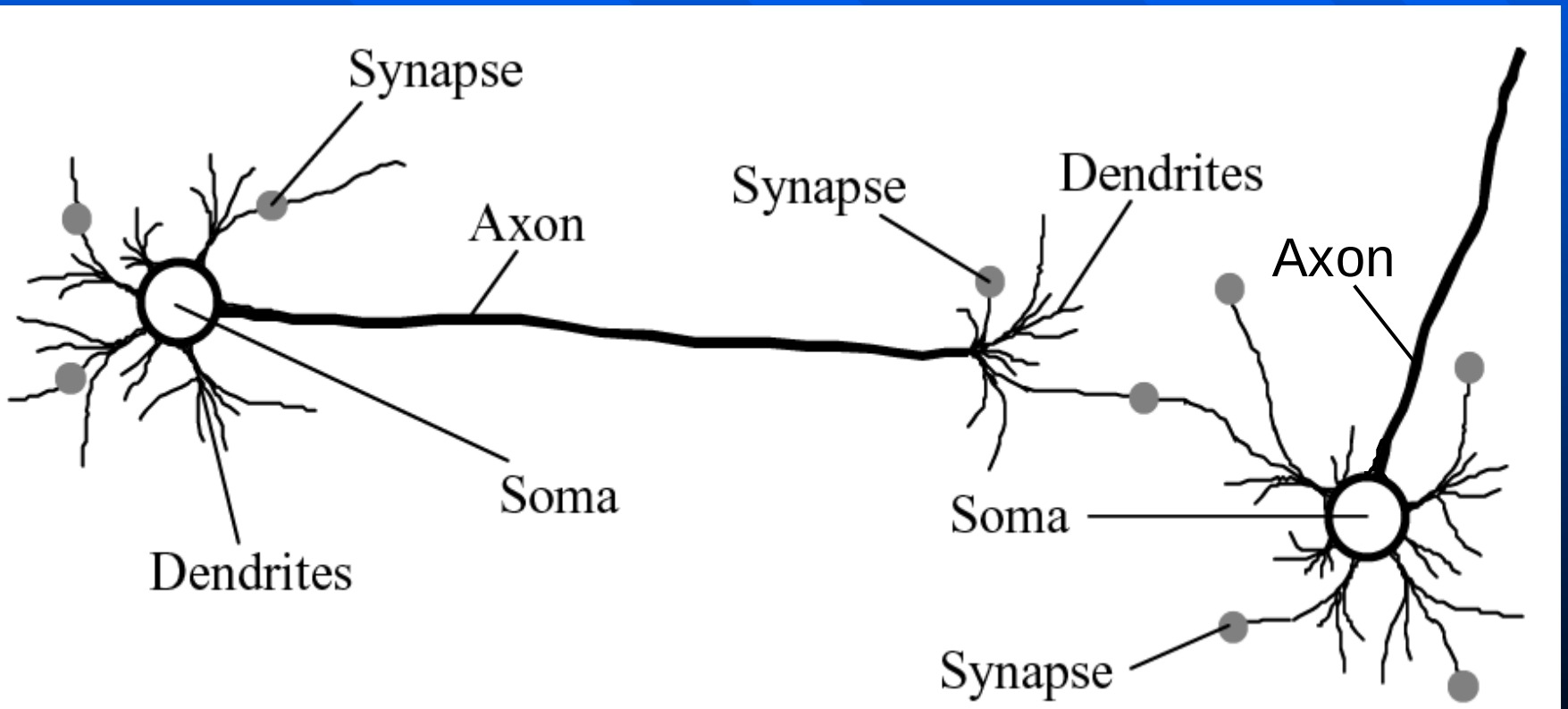
- Like human brain, ANNs can learn to solve a particular problem based on machine learning strategy.
- Machine learning involves adaptive mechanisms that enable ANNs to learn from experience, learn by example and learn by analogy.
- Like human, learning capabilities can improve the performance of an ANN over time.
- However, an excessive training period can also deteriorate the performance of an ANN, just like how human's concentration tend to reduce after a certain point during a learning process.

Human Brain: The Biological NN

- As already mentioned artificial NN is modeled based on the human brain, the biological NN.
- The brain consists of a densely interconnected set of nerve cells, or basic information-processing units, called **neurons**.
- The human brain has about 10 billion neurons and 60 trillion connections between neurons, called ***synapses***.

Biological Neural Network Structure

- A neuron consists of a cell body, **soma**, a number of fibers called **dendrites**, and a single long fiber called the **axon**. **Synapse** is a junction between dendrites, connecting one neuron to another.



The Working of Human Brain

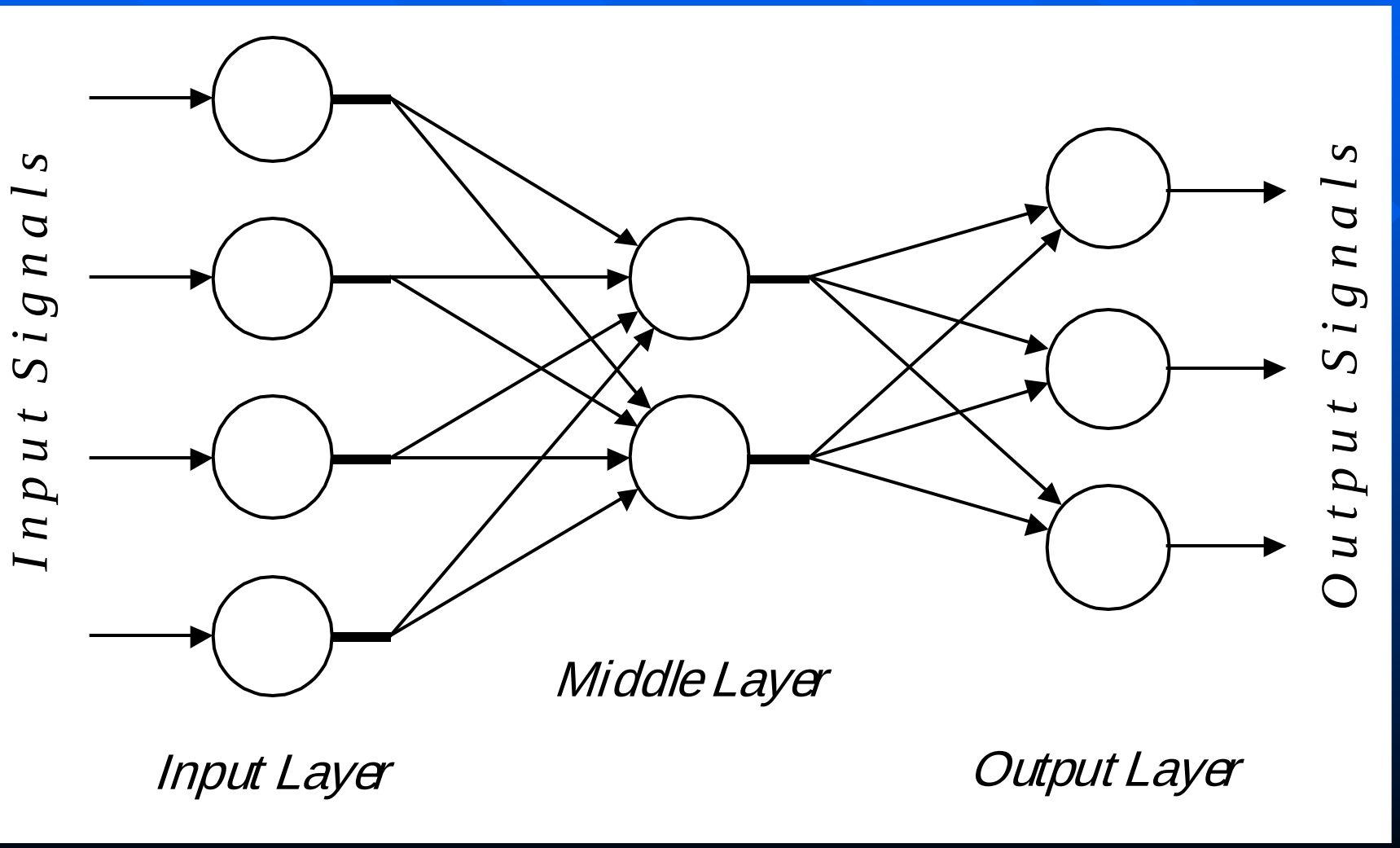
- Human brain can be considered as a highly complex, non-linear and parallel information-processing system.
- Information is stored and processed in a neural network simultaneously throughout the whole network, rather than at specific locations. In other words, in biological neural networks, both data and its processing are **global** rather than local.

Artificial Neural Network

- An artificial neural network is a system consisting of a number of simple processors, called **neurons** or **nodes**, which are analogous to the biological neurons in the brain. These neurons are processing or computational units or elements.
- The neurons are connected by weighted links, analogous to the synapse of biological neuron, passing signals from one neuron to another.
- The output signal is transmitted through the neuron's outgoing connection, analogous to the axon of biological neuron.

Artificial Neural Network Structure

- The outgoing connection may split into a number of branches that transmit the same signal. The outgoing branches connect to other neurons as inputs.

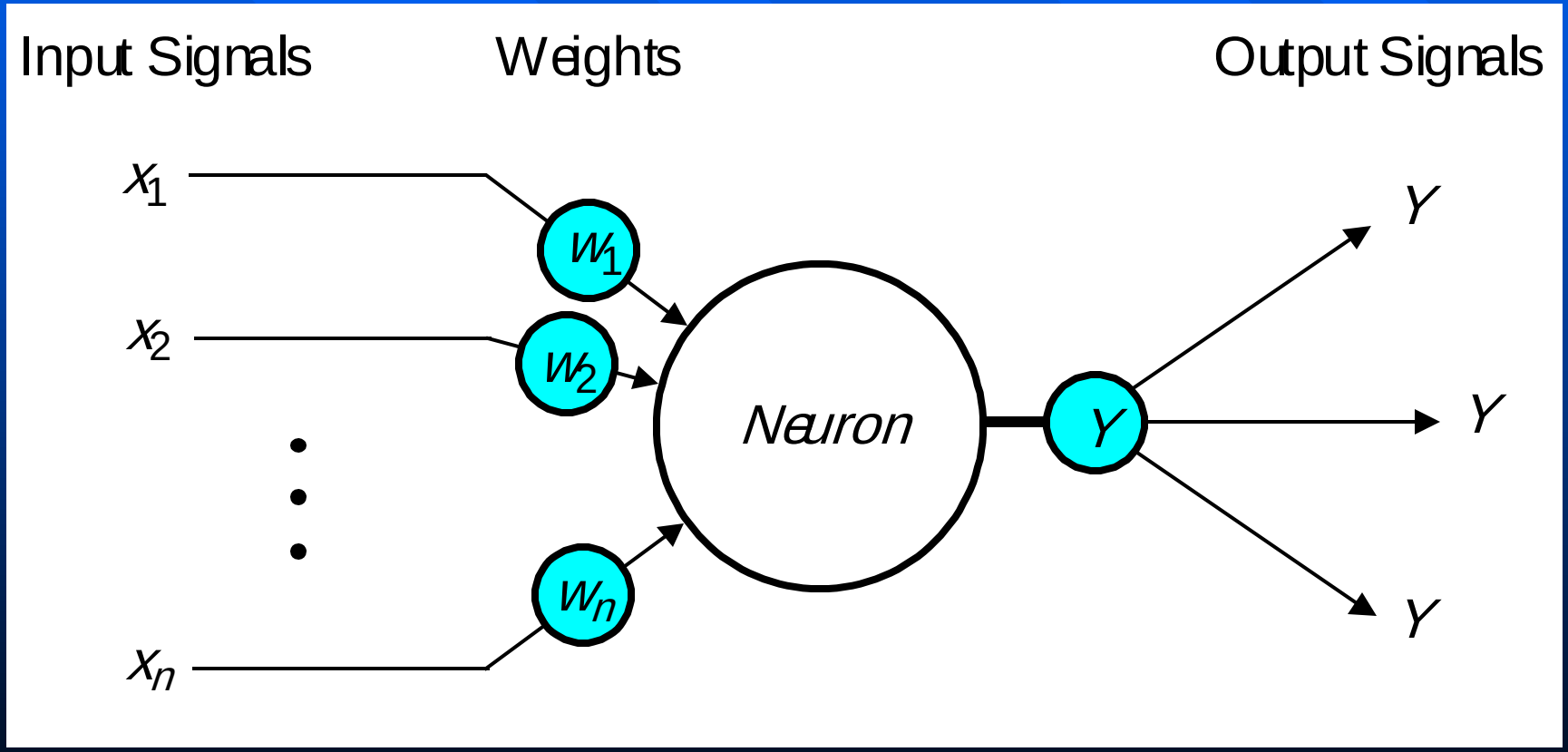


Analogy between biological and Artificial Neural Networks

Biological Neural Network	*Artificial Neural Network*
Soma	Neuron
Dendrite	Input
Axon	Output
Synapse	Weight

The neuron: A simple computing element

A neuron has inputs and outputs links or connections, These links have some weight values associated with them.



- The neuron computes the sum of weighted input signals and compares the result with a **threshold value**, θ. If the net input is less than the threshold, the neuron output is –1. But if the net input is greater than or equal to the threshold, the neuron becomes activated and its output attains a value +1.

- The neuron uses the following transfer or **activation function**:

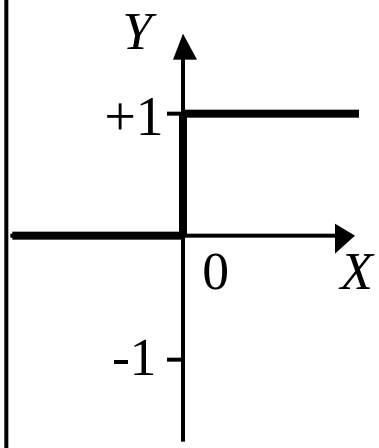
$$X = \sum_{i=1}^{n} x_i w_i \qquad Y = \begin{cases} +1, & \text{if } X \geq \theta \\ -1, & \text{if } X < \theta \end{cases}$$

- This type of activation function is called a **sign function**.

Activation functions of a neuron

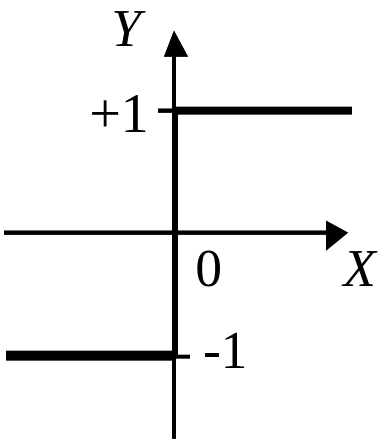
- There are various types of activation functions.
- Each type is problem or application dependent.
- Another commonly use sigmoid function is the hyperbolic tangent.

Step function



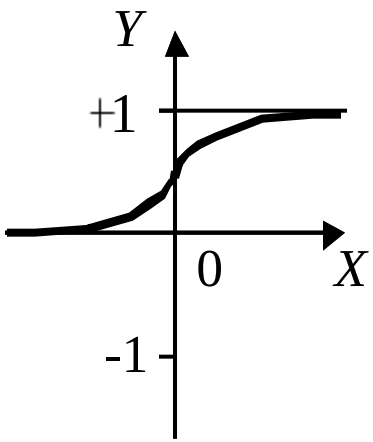
$$Y^{step} = \begin{cases} 1, \text{ if } X \geq 0 \\ 0, \text{if } X < 0 \end{cases}$$

Sign function



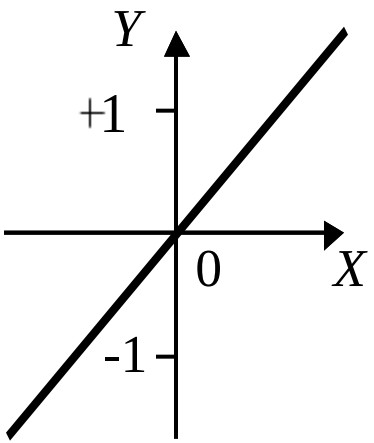
$$Y^{sign} = \begin{cases} +1, \text{if } X \geq 0 \\ -1, \text{if } X < 0 \end{cases}$$

Sigmoid function



$$Y^{sigmoid} = \frac{1}{1+e^{-X}}$$

Linear function



$$Y^{linear} = X$$

Characteristics of ANN

- Able to learn from given examples and use the learnt knowledge to generalize, producing outputs from unseen data. This is an important characteristic which needs to be achieved by an ANN.
- Capable of operating based on parallel methods (if implemented in such manner), making it a high-speed system.
- Fault tolerant – information distributed to other neurons make it still in operation although few neurons are corrupted.
- Able to solve not only linear problems, but also non-linear problems

Learning in ANN

- ANN learns by running a training algorithm, taking samples of inputs and corresponding outputs as examples.
- In 1958, **Frank Rosenblatt** introduced a training algorithm that provided the first procedure for training a simple ANN: a **perceptron**.
- The perceptron is the simplest form of a neural network system. It consists of a single neuron with *adjustable* synaptic weights and a *hard limiter*.