KTU LECTURE NOTES

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

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INTRODUCTION TO SOFT COMPUTING

LECTURE 1

November 26, 2017

Introduction

- The idea of soft computing was initiated in 1981, by Lotfi A Zadeh.
- The role model for soft computing is human mind.
- Soft computing is a term used in computer science to refer to problems, whose solutions are unpredictable, uncertain and between 0 and 1.
- Designed to model solutions to real world problems, which are not modeled or too difficult to model mathematically.

Problem Solving Techniques

Two Techniques:

1. Hard Computing
2. Soft Computing

Problem Solving Techniques

Two Techniques:

1. Hard Computing: deals with precise models where accurate solutions are achieved quickly.
2. Soft Computing: deals with approximate models and gives solutions to complex problems.

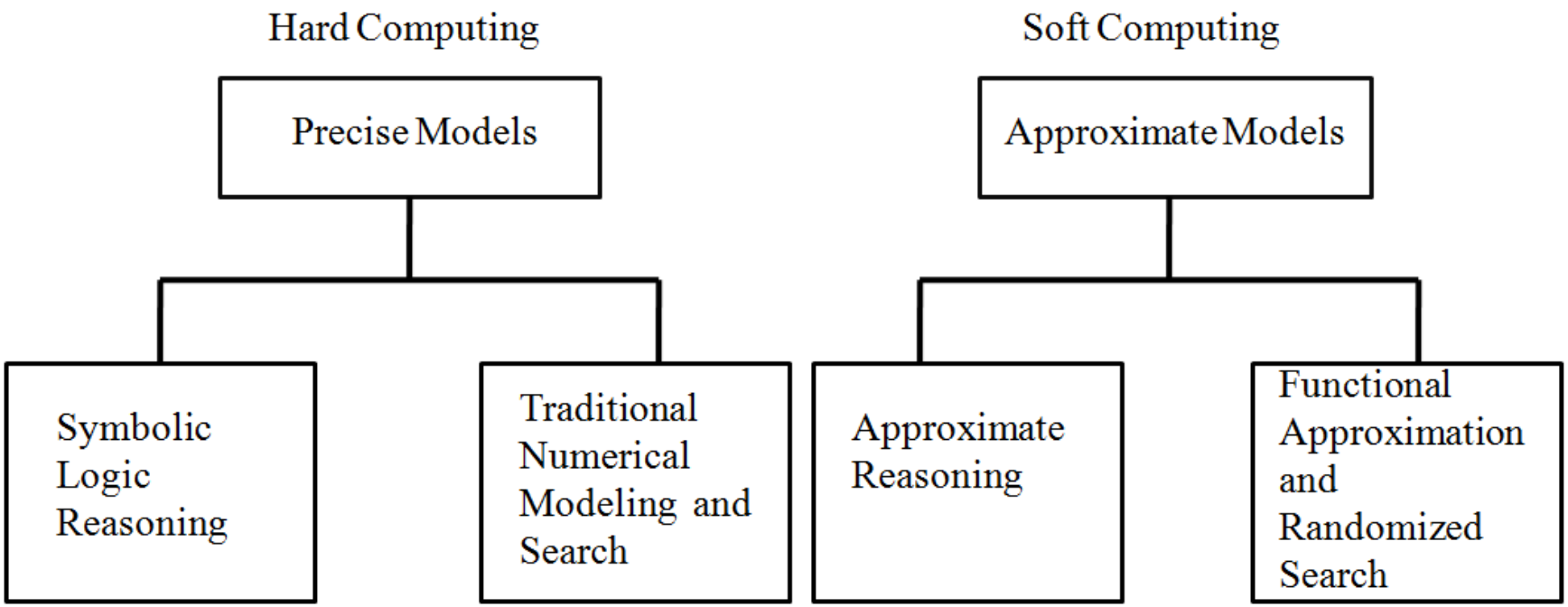

Figure 2.1: Problem Solving Technologies

Comparison

Table 2.1: Hard Computing VS Soft Computing

Hard Computing	Soft Computing
Works well for simple problems	Well suited for real world problems
Requires precisely state analytic model	Tolerant of imprecision uncertainty, partial truth and approximation
Requires full truth	Can work with partial truth
Precise and accurate	Imprecise
Uses two−valued logic	Can use multivalued logic
Often requires a lot of computation time	Requires reasonably less time

Definitions of Soft Computing

Sometimes referred to as "*Cognitive computing*"

"*Soft computing is an emerging approach to computing, which parallel the remarkable ability of the human mind to reason and learn in an environment of uncertainity and imprecision.* "

Definitions of Soft Computing

"Soft computing as an attempt to mimic natural creatures: plants, animals, human beings, which are soft, flexible, adaptive and clever. In this sense, soft computing is the name of a family of problem–solving methods that have analogy with biological reasoning and problem solving."

Definitions of Soft Computing

"Soft computing is a branch, in which, it is tried to build intelligent and wiser machines. Intelligence provides the power to derive the answer and not simply arrive to the answer. The final aim is to develop a computer or machine which will work in a similar way as human beings can do, ie, the wisdom of human beings can be replicated in computers in some artificial manner."

Goals

1. To develop intelligent machines to provide solutions to real world problems, which are not modeled, or too difficult to model mathematically.
2. To exploit the tolerance for *Approximation, Uncertainity, Imprecision and Partial Truth* inorder to achieve close resemblance with human like decision making.
3. To exploit these tolerances to achieve *tractability, robustness, and low solution cost*.

Approximation: here the model features are similar to the real ones, but not the same.

Uncertainity: here we are not sure that the features of the model are the same as that of the entity (*belief*).

Imprecision: here the model features (*quantities*) are not the same as that of the real ones, but close to them.

Advantages

1. It made for solving non−linear problems in which mathematical models are not available.
2. It introduced the human knowledge (*recognition, understanding, learning and others*) into the field of computing.

Why soft computing approach?

- Human can:
  1. take decisions
  2. inferences from previous situation experienced
  3. expertise in an area
  4. adapt to changing environment
  5. learn to do better
  6. social behavior of collective intelligence

Why soft computing approach?

- Human can:
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Fuzzy Logic

Neural Networks

Evolutionary algorithms

These methodologies form the core of soft computing.

How do neural networks differ from conventional computing?

- A *serial computer* has a central processor. In this system, computational steps are deterministic, sequential.
- *Neural networks* are not sequential or necessarily deterministic. There are no central processors.

Introduction to Neural Networks(NN)

"*...a computing system made up of a number of simple, highly interconnected processing elements, which process an information by their dynamic state response to the external inputs.*"

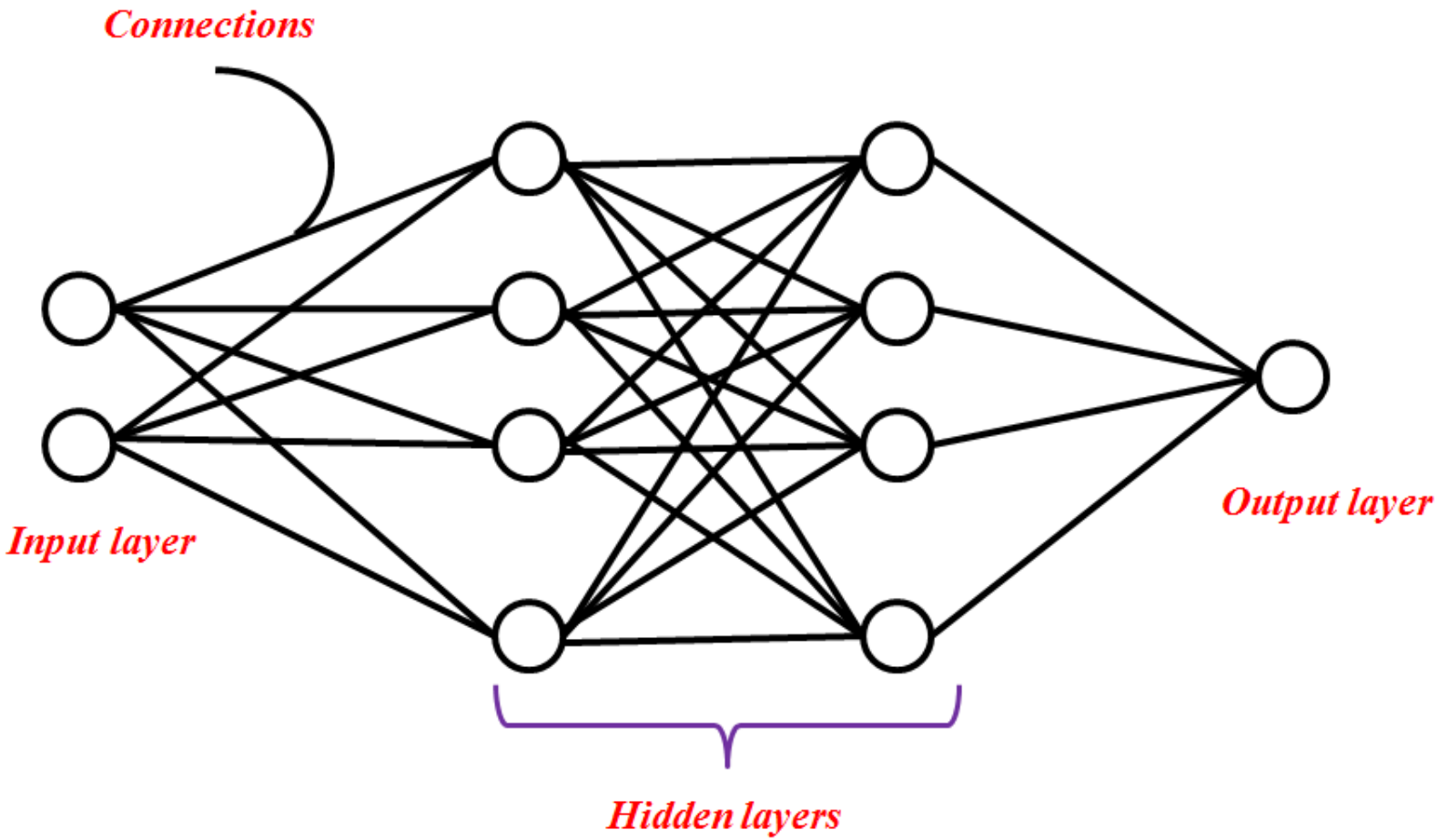
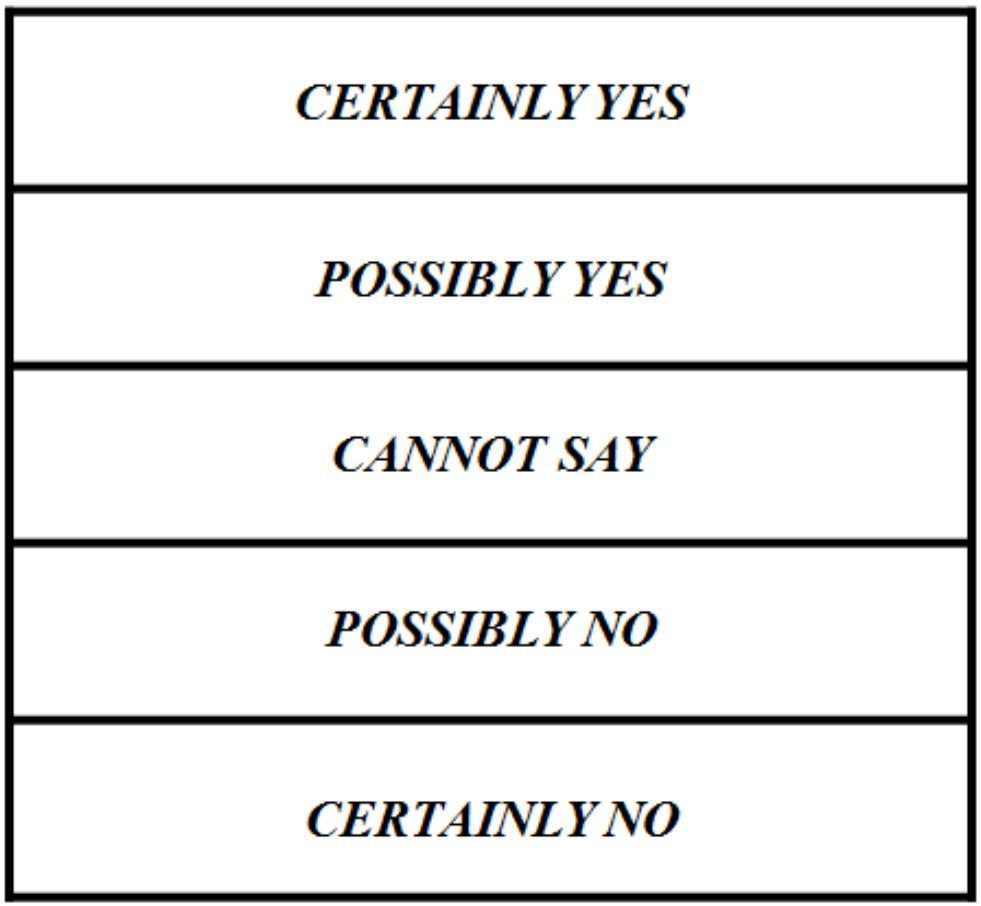


Figure 4.1: Neural Network Architecture

What is Fuzzy Logic(FL)?

- A method of reasoning that resembles human reasoning.
- FL imitates the way of decision making in humans that involves all intermediate possibilities between digital values YES and NO(0 and 1).
- The human decision making includes a range of possibilities between YES and NO such as:



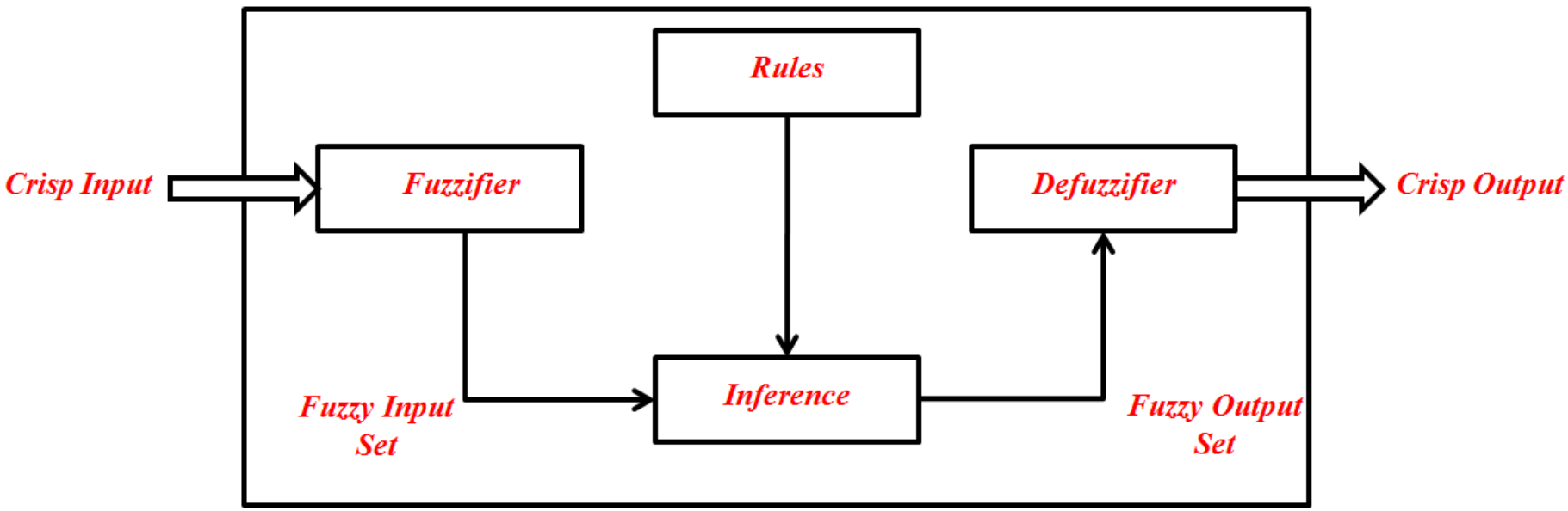


Figure 4.2: Fuzzy Logic System Architecture

Genetic Algorithms(GA)

- Search−based optimization technique based on the principles of *genetics and natural selection*.
- To find optimal solutions to difficult problems which otherwise would take a lifetime to solve.
- The main idea is survival of the fittest.

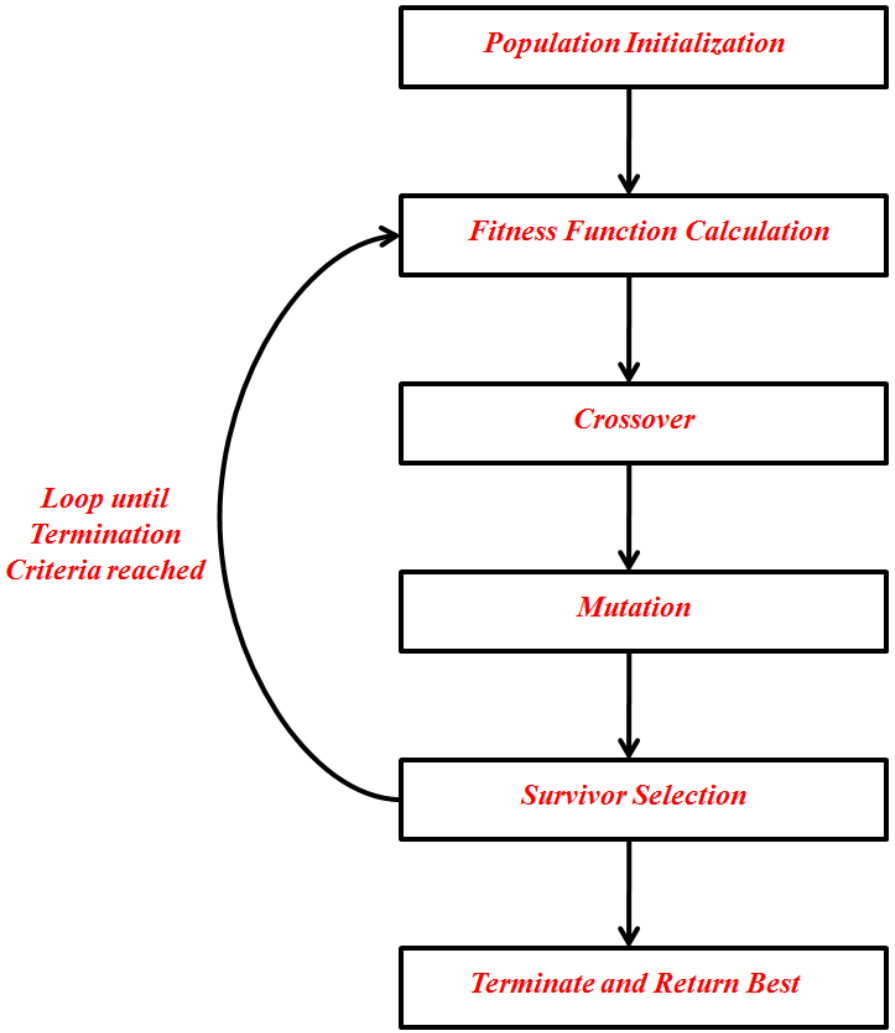


Figure 4.3: Basic structure of GA

Comparison

Table 4.1: Classical Algorithm VS Genetic Algorithm

Classical Algorithm	Genetic Algorithm
Generates a single point at each iteration. The sequence of points approaches an optimal solution.	Generates a population of points at each iteration. The point in the population approaches an optimal solution.
Select the next point in the sequence by a deterministic computation.	Select the next population by computation which uses random number generators.

ARTIFICIAL NEURAL NETWORK (ANN)

LECTURE 2

November 26, 2017

Fundamental Concept

- NNs are constructed and implemented to model the human brain.
- The main objective is to develop computational device for modeling the brain to perform various tasks.
- ANNs are implemented using *high speed digital computers* which makes the simulation of neural processes feasible.

ANN

- ANNs possess large number of highly interconnected processing elements called *nodes or units or neurons*.
- Operates in parallel.
- ANNs collective behavior is characterized by their,
  1. ability to learn
  2. recall
  3. generalize training patterns or data

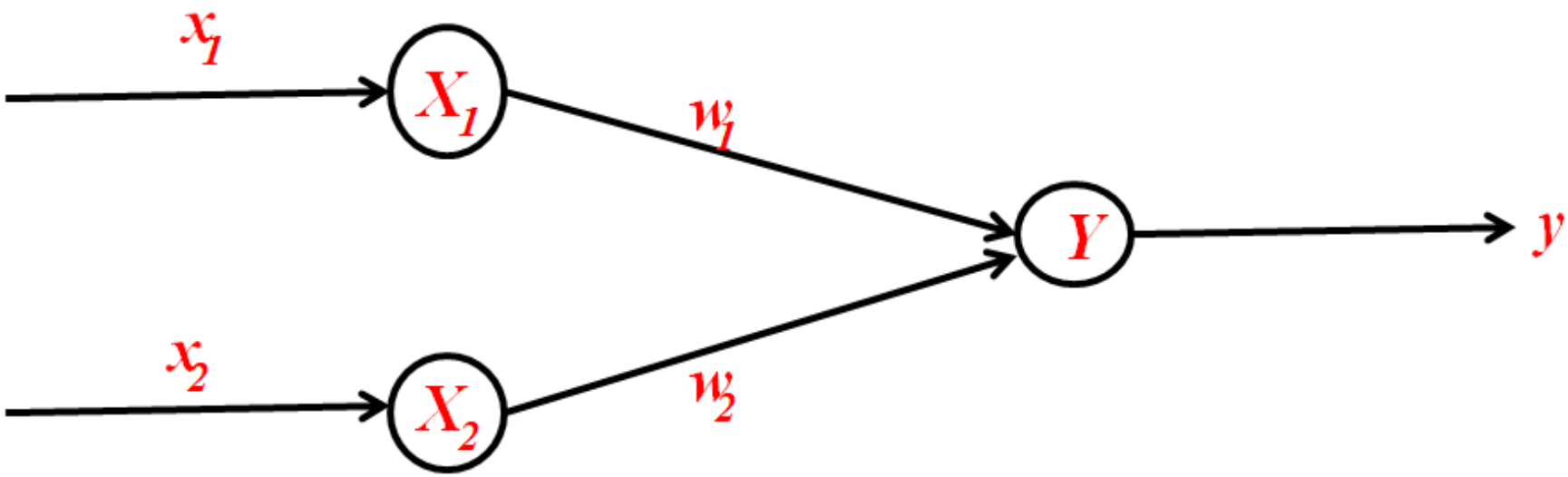
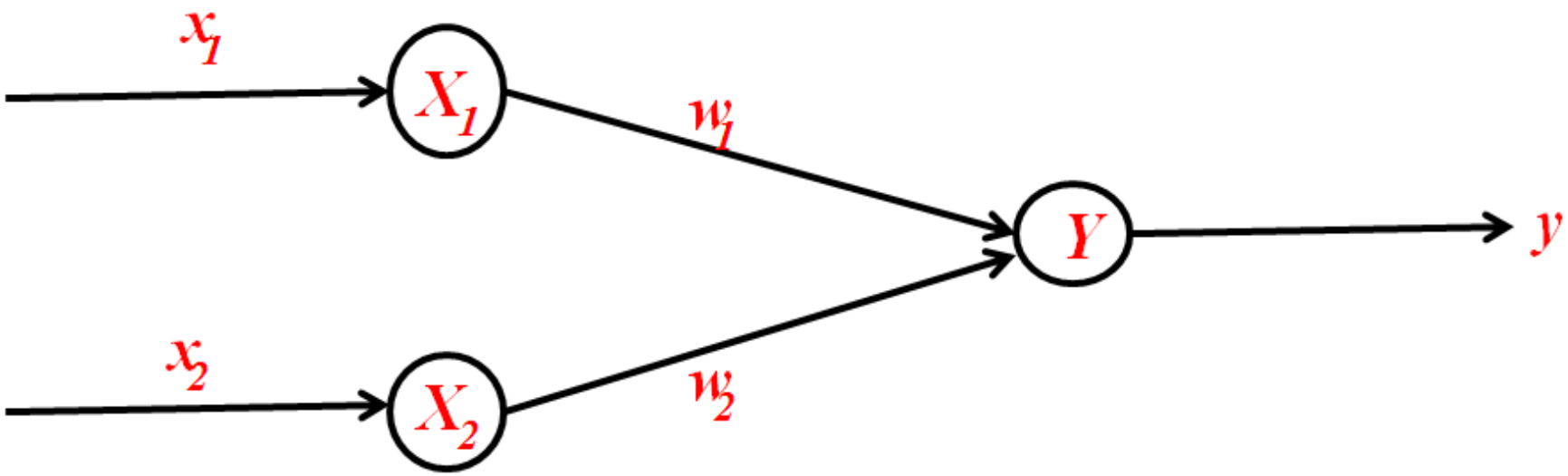


Figure 1.1: Architecture of a simple artificial neural net



$$Net\ input,\ y_{in} = x_1 w_1 + x_2 w_2$$

$$y = f(y_{in})$$

$$Output = Function(net\ input\ calculated)$$

Biological Neural Network

- Human brain consists of a huge number of neurons with numerous interconnections.

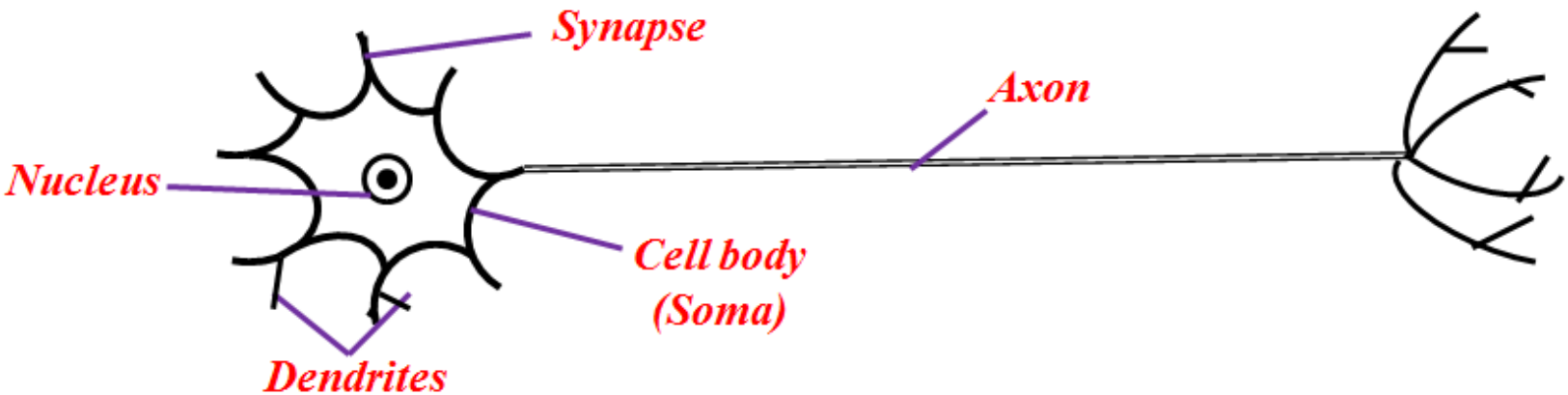
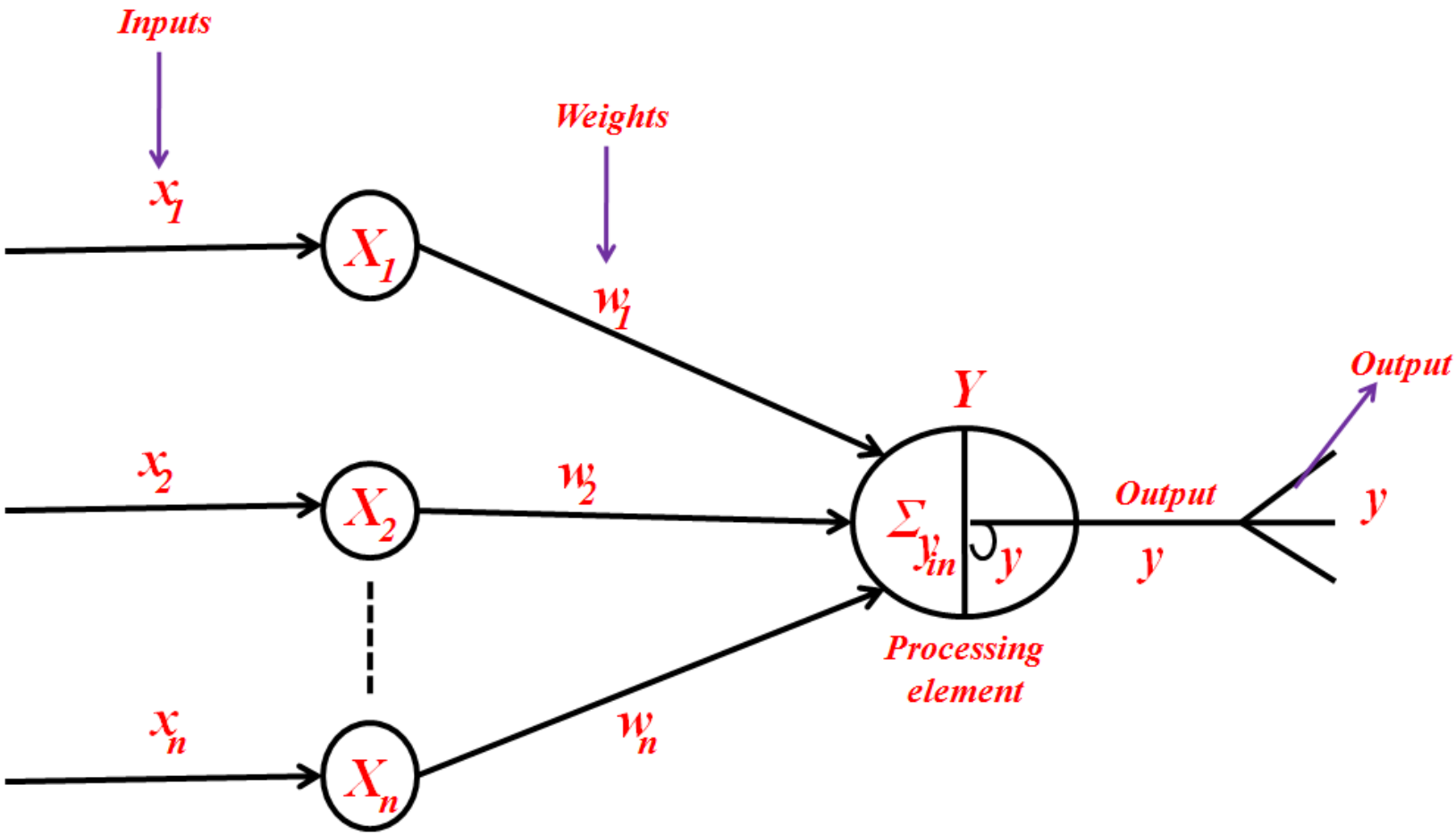
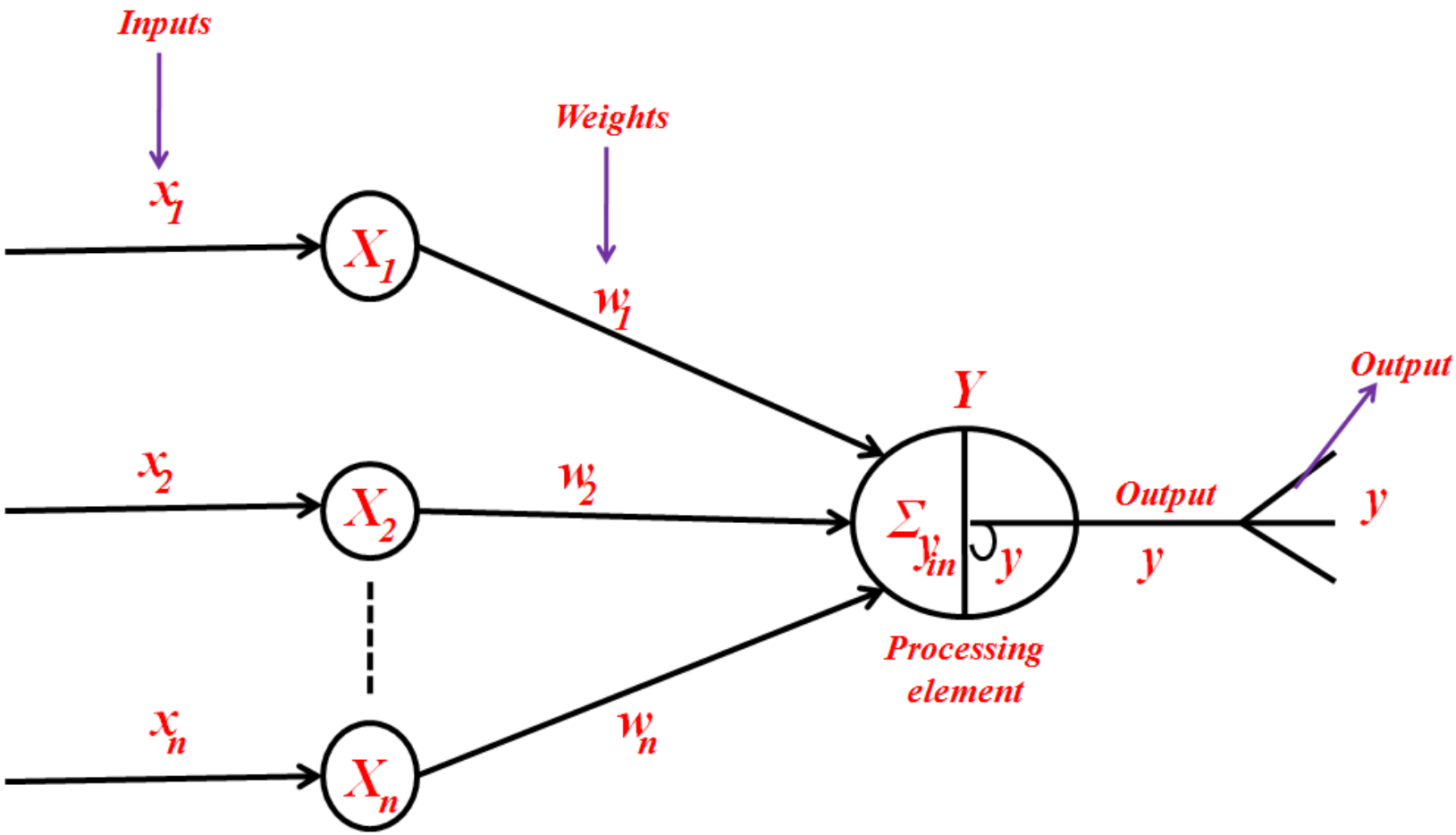


Figure 1.2: Schematic diagram of a biological neuron

Mathematical model of artificial neuron



Mathematical model of artificial neuron



Net input, $y_{in} = x_1 w_1 + x_2 w_2 + ... + x_n w_n = \sum_{i=1}^{n} x_i w_i$

Terminology relationships between biological and artificial neurons

Biological neuron	Artificial neuron
Cell	Neuron
Dendrites	Weights or interconnections
Soma	Net input
Axon	Output

Comparison between biological neuron and artificial neuron

Table 1.1: Brain Vs Computer

Criteria	Artificial neuron	Biological neuron
Speed	The cycle time of execution in the ANN is of few nanoseconds.	It is of few milli seconds.
Processing	Can perform several parallel operations simultaneously.	Can perform massive parallel operations simultaneously.
Size and Complexity	Size and complexity is based on the chosen application and the network designer.	Total number of neurons is about 10^{11} and the total number of interconnections is about 10^{15}. Complexity is comparatively higher.

Table 1.2: Brain Vs Computer(Contd..)

Criteria	Artificial neuron	Biological neuron
Storage Capacity	Stores in its contiguous memory locations.	Stores the information in its interconnections or in synapse.
Tolerance	Has no fault tolerance	Possesses fault tolerant capability
Control Mechanism	Yes	No

Characteristics of ANN

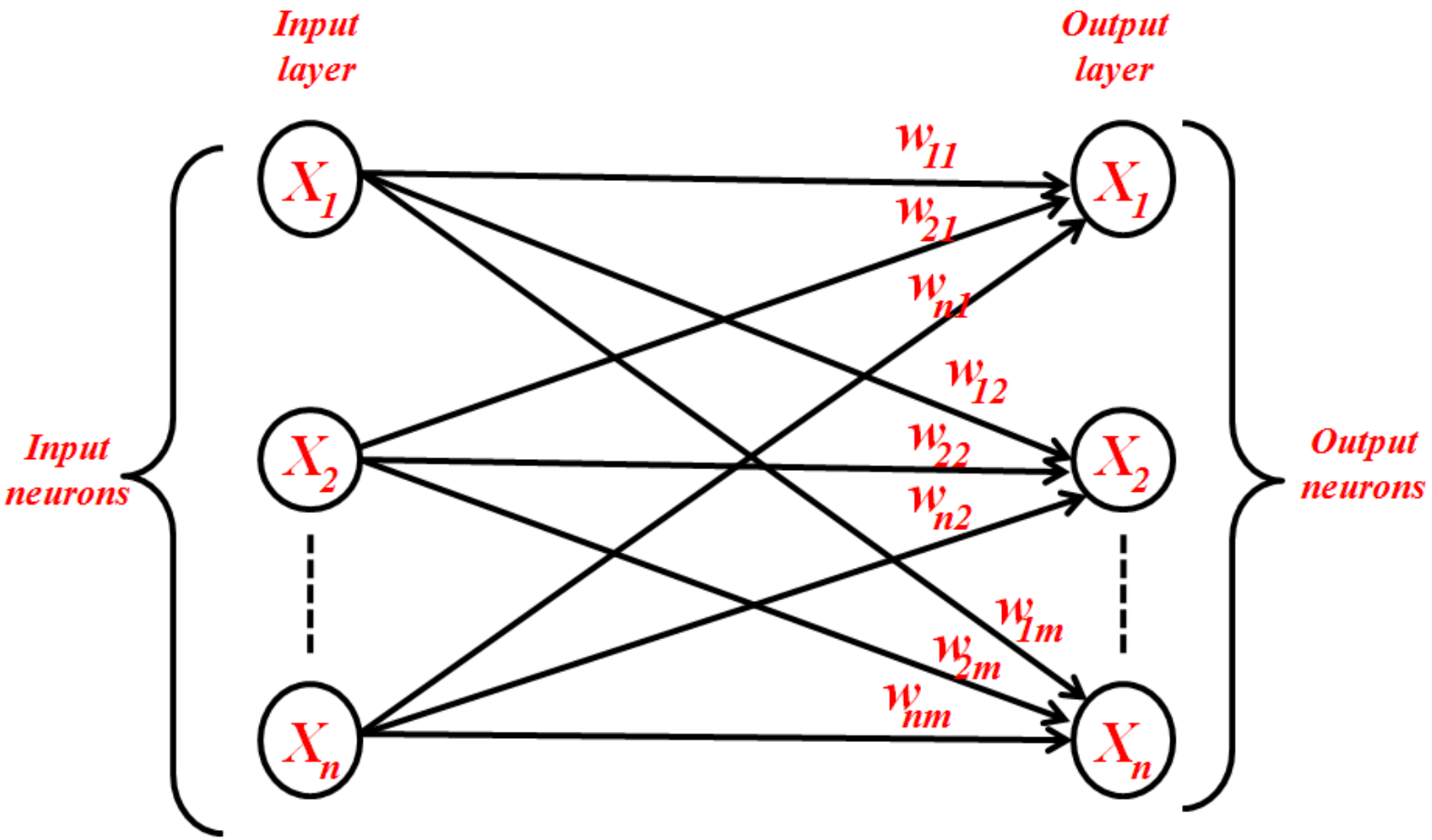
1. It is a neurally implemented mathematical model.
2. There exist a large number of highly interconnected processing elements called *neurons* in an ANN.
3. The interconnections with their weighted linkages hold the informative knowledge.
4. The input signals arrive at the processing elements through connections and connecting weights.
5. The processing elements of the ANN have the *ability to learn, recall, and generalize from the given data by suitable assignment or adjustment of weights*.
6. No single neuron carries specific information.

Connections

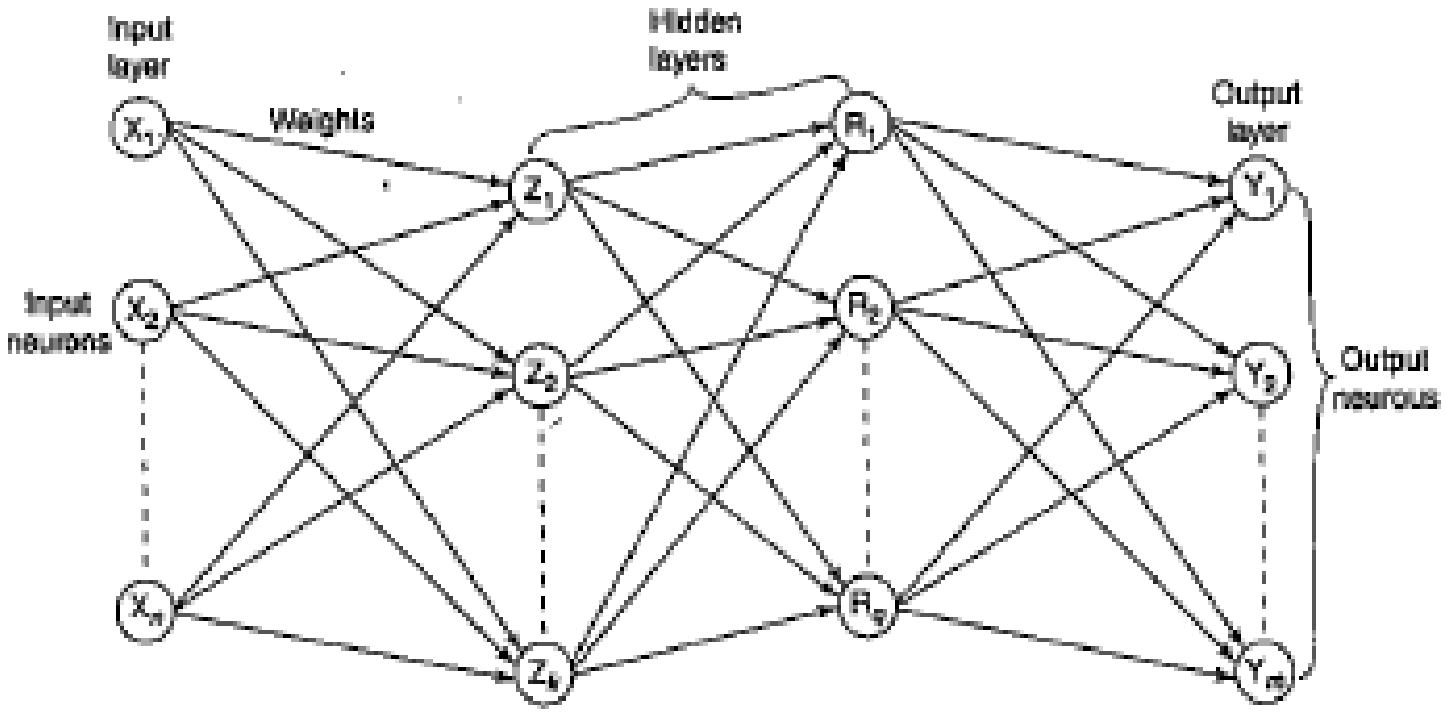
- The point where the connection originates and terminates should be noted.
- The arrangements of neurons to form layers and the connection pattern formed within and between layers is called the *network architecture*.

1. single−layer feed−forward network
2. multilayer feed−forward network
3. single−layer with its own feedback
4. single−layer recurrent network
5. multilayer recurrent network

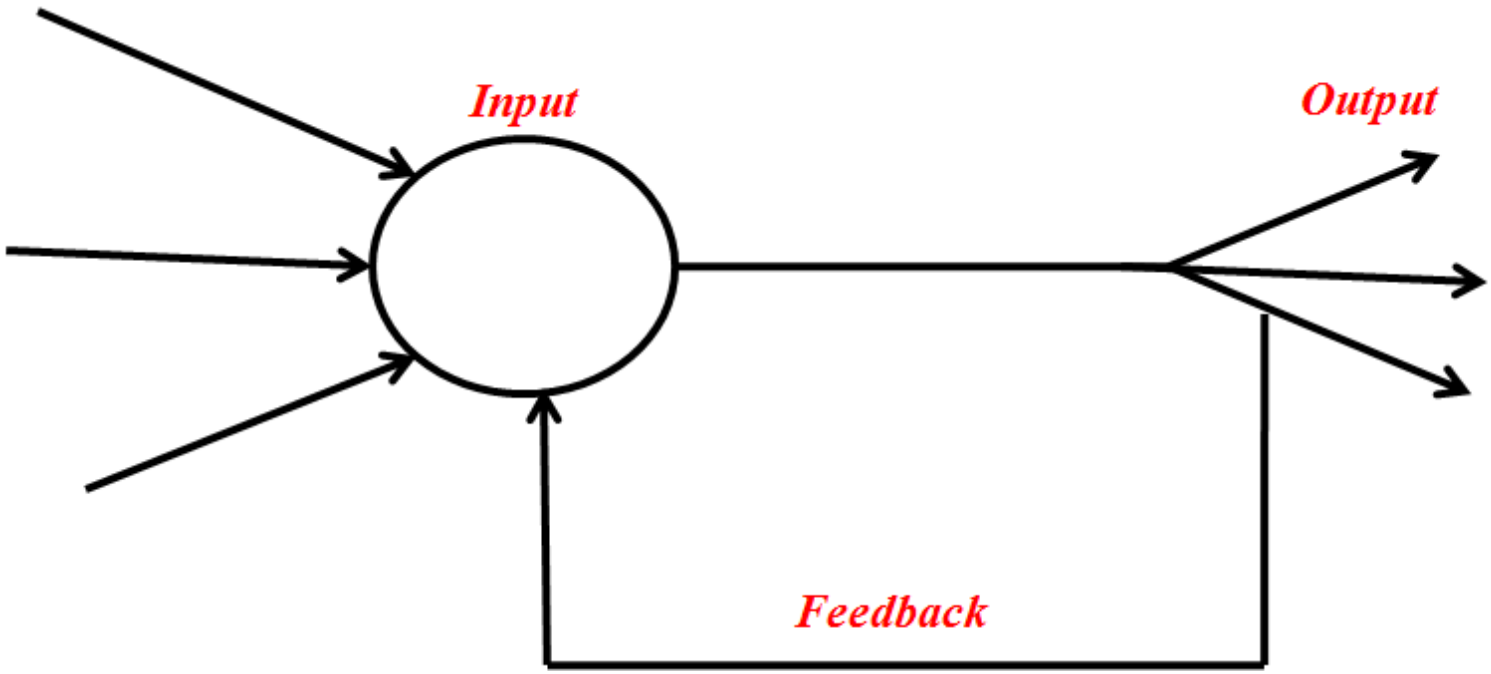
Single−layer feed−forward network



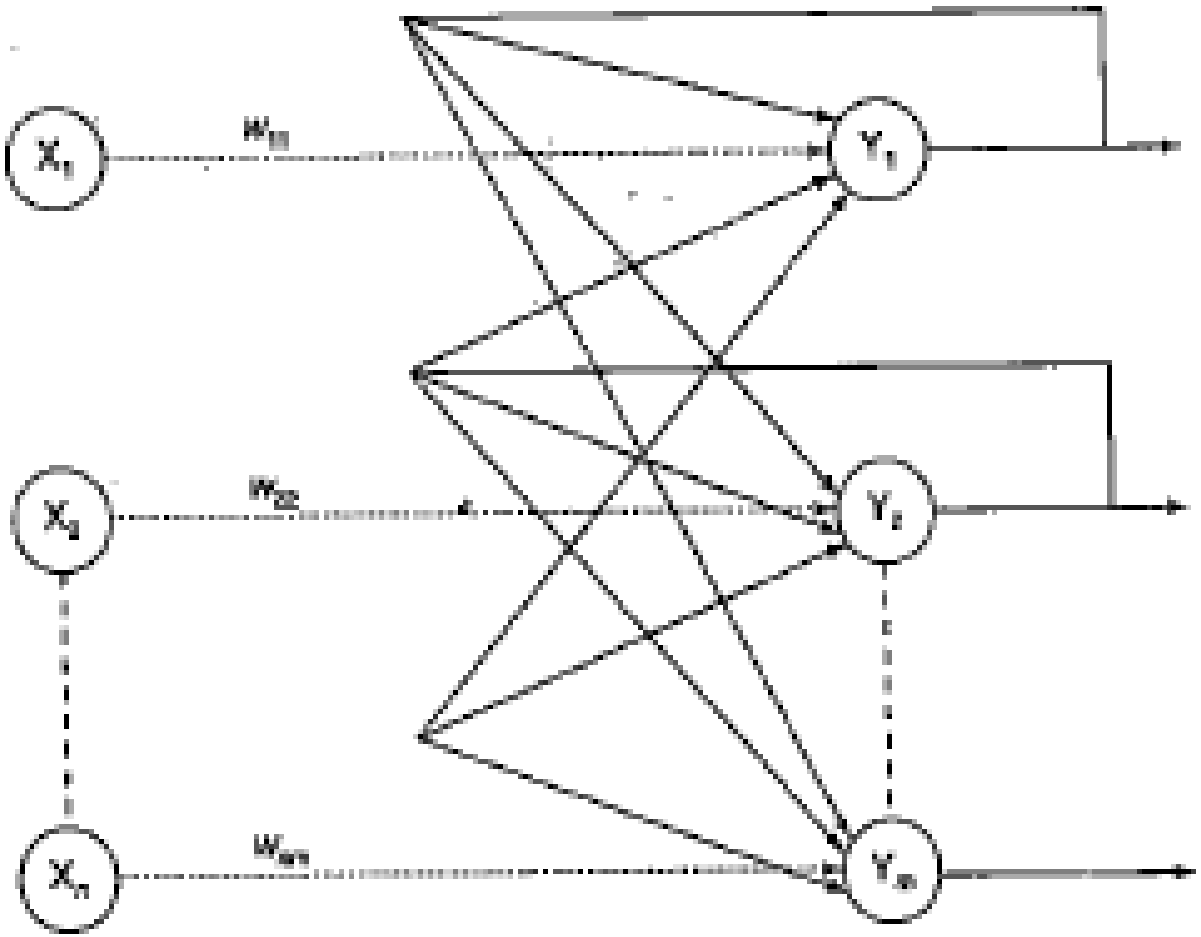
Multilayer feed−forward network



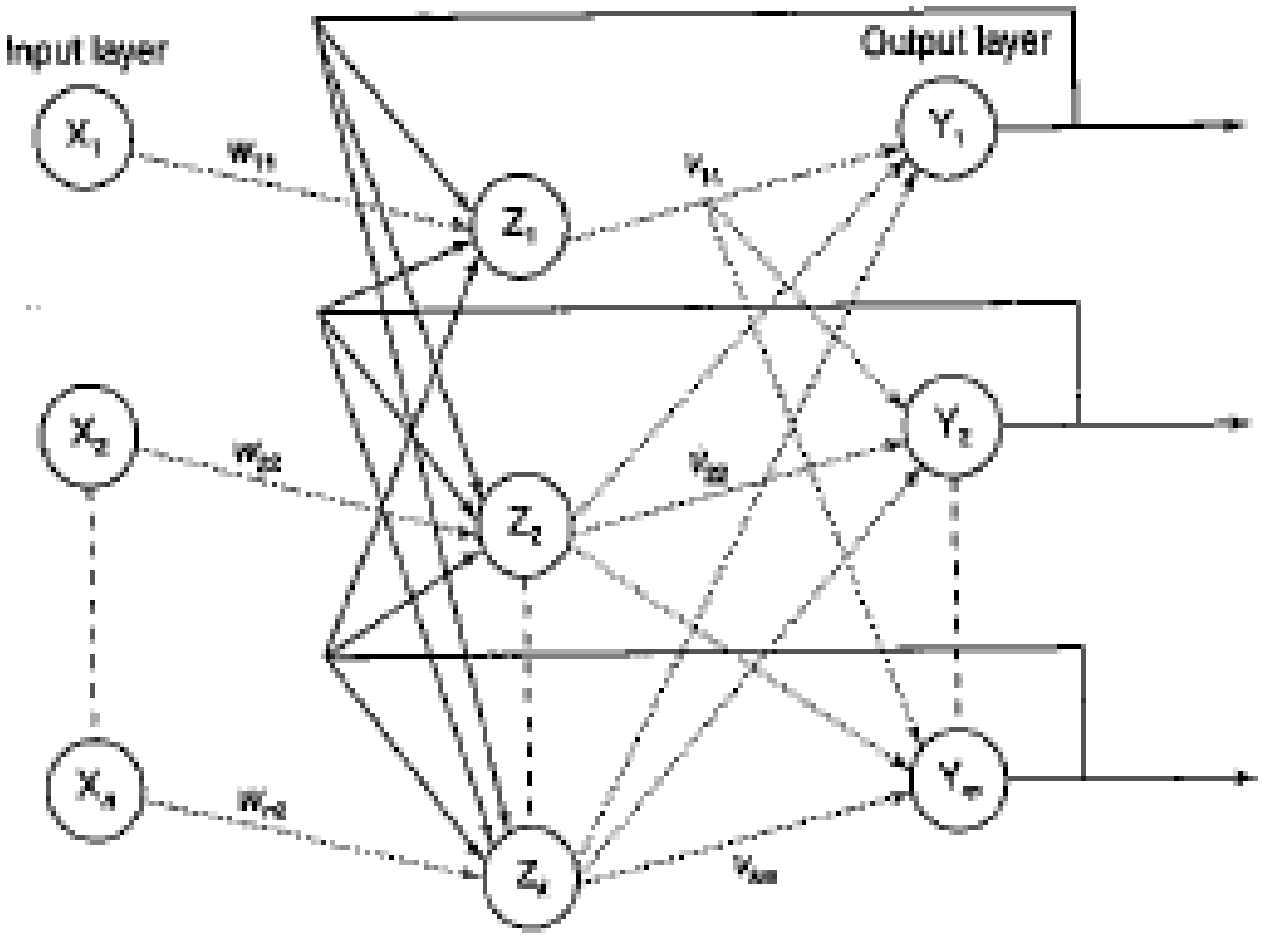
Single−layer with its own feedback



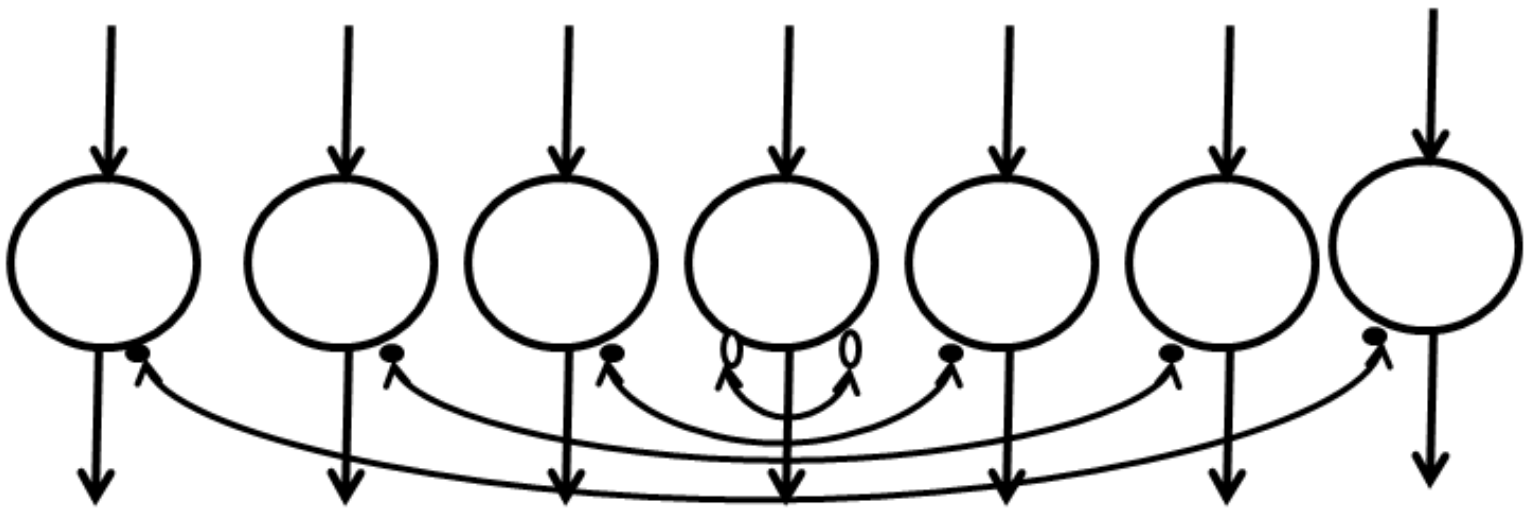
Single−layer recurrent network



Multilayer recurrent network



On−center−off−surrounded or Lateral inhibition structure



Learning

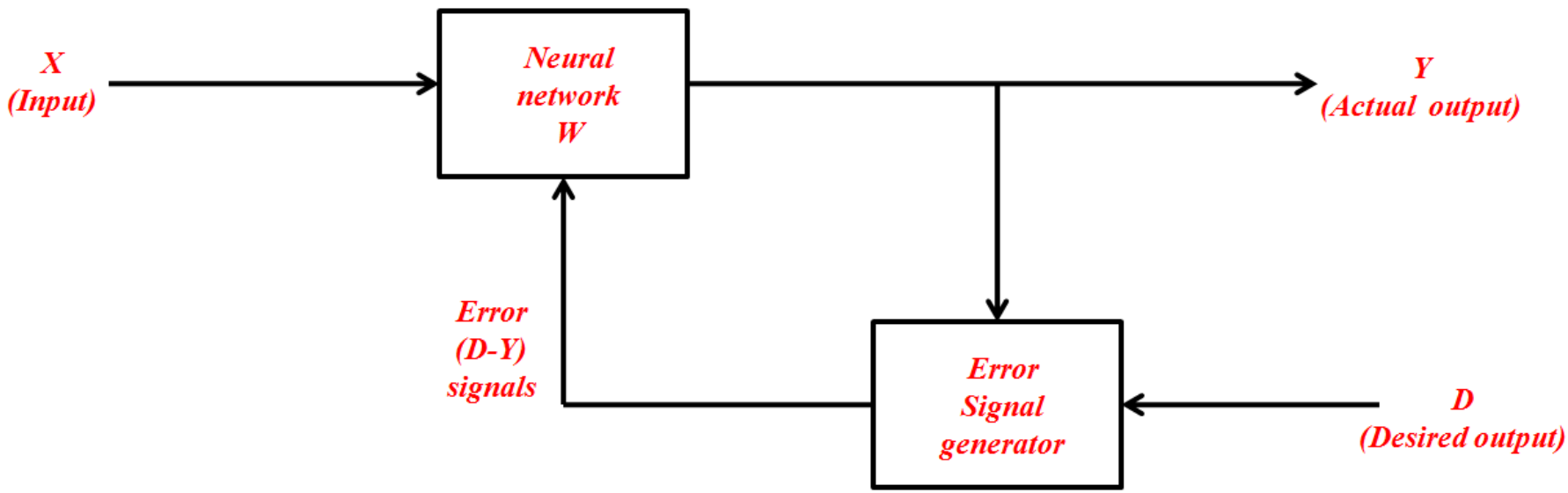
- *Learning or training* is a process, which a NN adapts itself to a stimulus by making proper parameter adjustments, resulting in the production of desired response.
- Two kinds of learning:

1. Parameter learning: It updates the connecting weights in a neural net.
2. Structure learning: It focuses on the change in network structure.

Categories

1. Supervised learning
2. Unsupervised learning
3. Reinforcement learning

Supervised Learning



Categories

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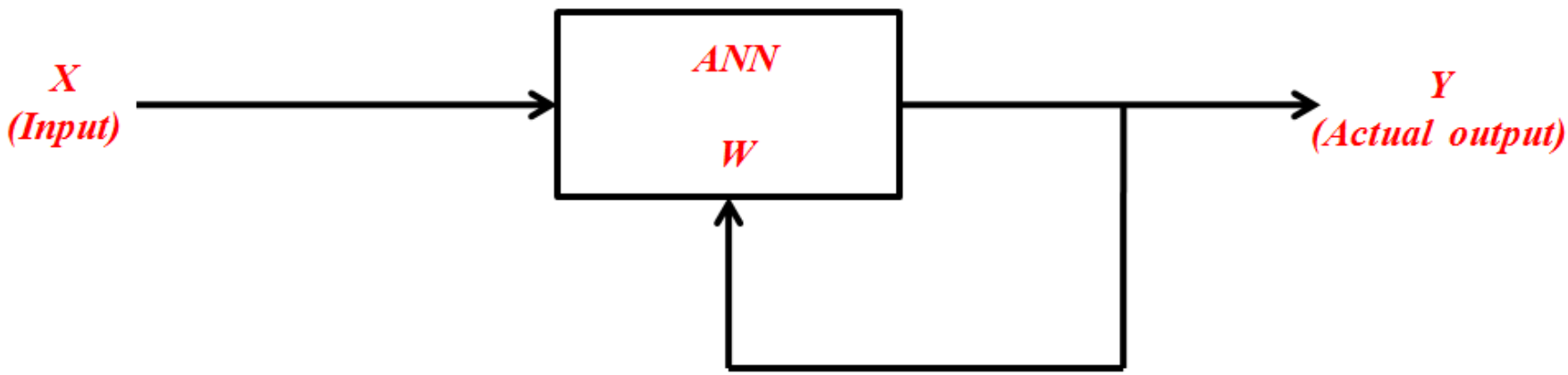
Unsupervised Learning



Categories

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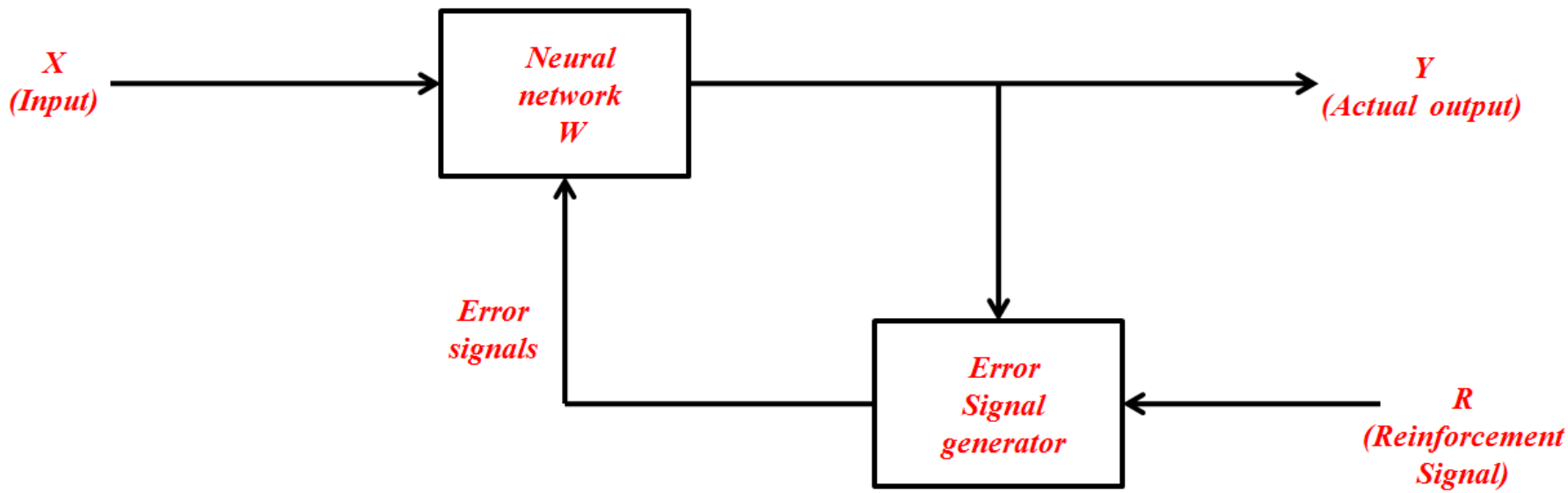
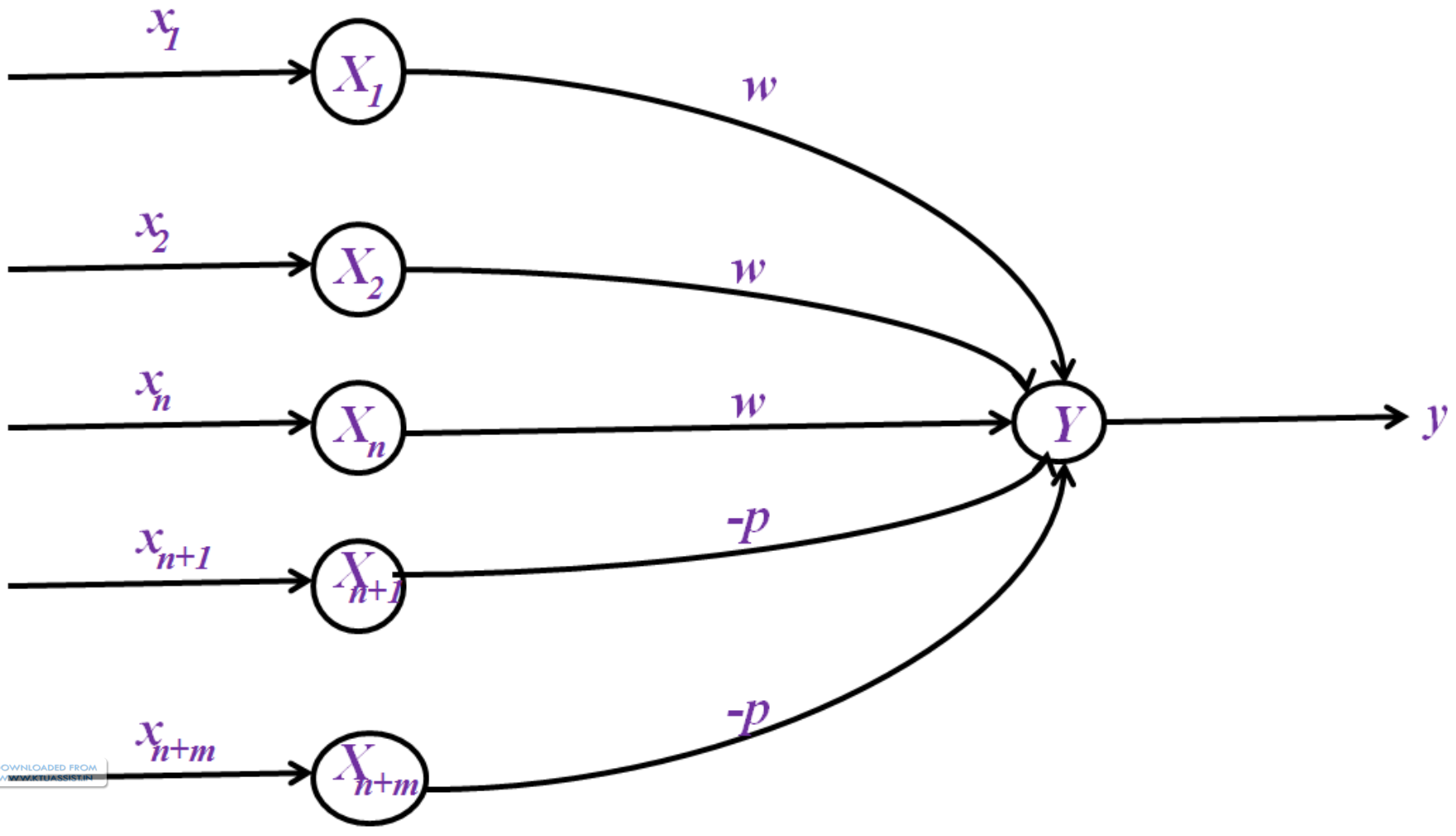
Reinforcement Learning



McCulloch−Pitts Neuron

- Usually called as *M−P neuron*.
- Connected by directed weighted paths.
- Activation of a M−P neuron is binary.
- The weights associated with the communication links may be *excitatory(weight is positive)* or *inhibitory(weight is negative)*.
- The threshold plays a major role in the M−P neuron.

Architecture



Hebb Network

Donald Hebb stated that:

"When an axon of cell A is near enough to excite cell B, and repeatedly or permanently takes place in firing it, some growth process or metabolic change take place in one or both the cells such that A's efficiency, as one of the cells firing B, is increased."

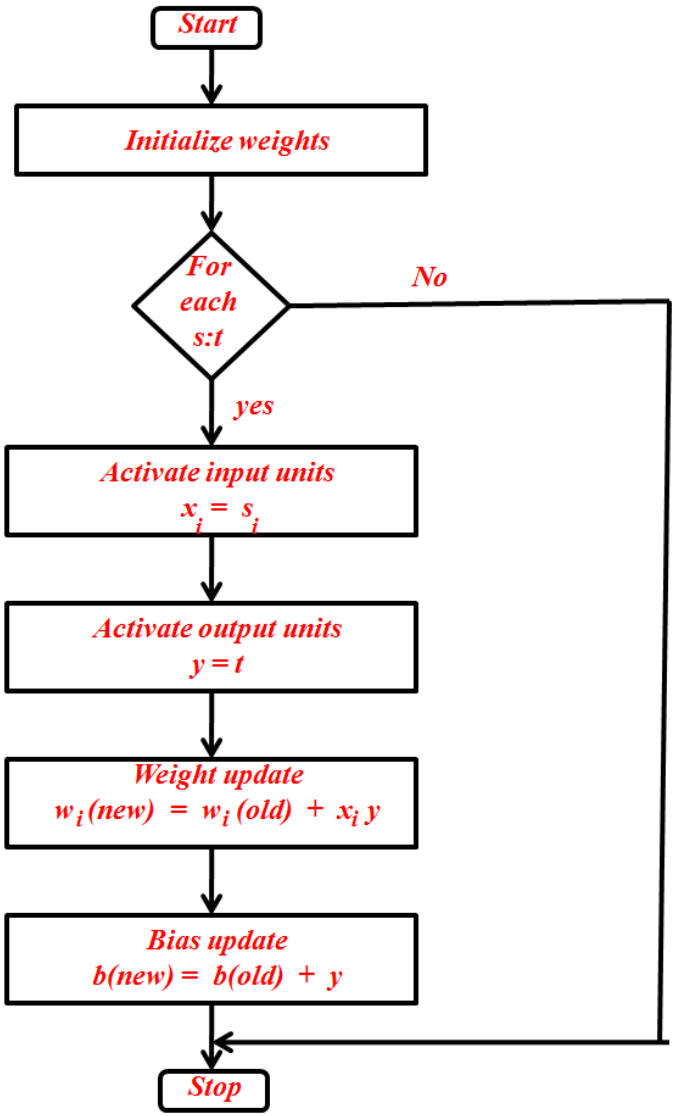
Theory

- The weight vector is found to increase proportionally to the product of the input and learning signal(learning signal is equal to the neuron′s output).
- In Hebb learning, if the two interconnected neurons are *on* simultaneously, then the weight associated with these neurons can be increased by the modification made in their weight.
- The weight update is given by,

$$w_i(new) = w_i(old) + x_i y$$

- The Hebb rule is more suited for bipolar data than binary data.

Flowchart of Hebb training algorithm



Training Algorithm

- *Step 0*: Initialize the weights.

$$w_i = 0 \text{ for } i = 1 \text{ to } n$$

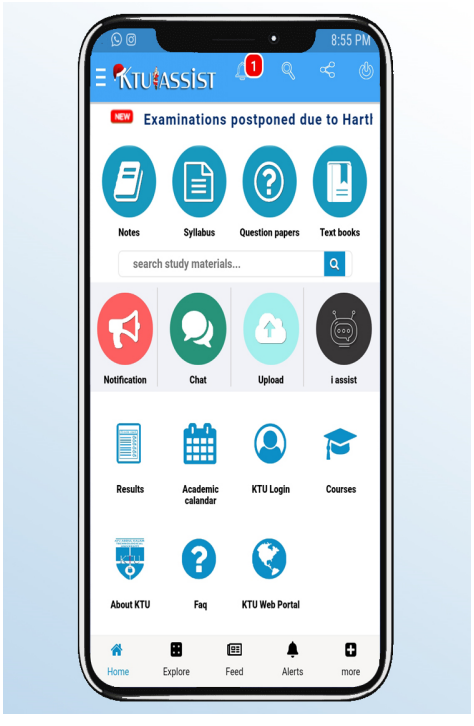
- *Step 1*: Steps 2–4 have to be performed for each input training vector and target output pair, $s : t$.
- *Step 2*: Input units activations are set.

$$x_i = s_i \text{ for } i = 1 \text{ to } n$$

- *Step 3*: Output units activations are set. $y = t$
- *Step 4*: Weight adjustments and bias adjustments are performed.

$$w_i(new) = w_i(old) + x_i y$$
$$b(new) = b(old) + y$$
$$\text{Change in weight, } \Delta w = xy$$

END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