Chapter 2

Fundamentals of Artificial Neural Network (ANN)

4th Class

INTELLIGENT APPLICATIONS

التطبيقات الذكية

إعداد المحاضرة : م.م. ايمان حسين رحيم

أستاذة المادة الدراسة الصباحية : د. ايناس محمد حسين

أستاذة المادة الدراسة المسائية : م.م. ايمان حسين رحيم

Fundamentals of Artificial Neural Network (ANN)

2.1 Introduction

A neural net is an artificial representation of the human brain that tries to simulate its learning process. An artificial neural network (ANN) is often called a "Neural Network" or simply Neural Net (NN).

Traditionally, the word neural network is referred to a network of ***biological neurons*** in the nervous system that process and transmit information.

Artificial neural network is an interconnected group of artificial neurons that uses a mathematical model or computational model for information processing based on a connectionist approach to computation.

- Artificial Neural Networks (ANNs), like people**, learn by example.**

2.2 Biological Neuron Model

The human brain consists of a large number; more than a billion of neural cells that process information. Each cell works like a simple processor. The massive interaction between all cells and their parallel processing only makes the brain's abilities possible.

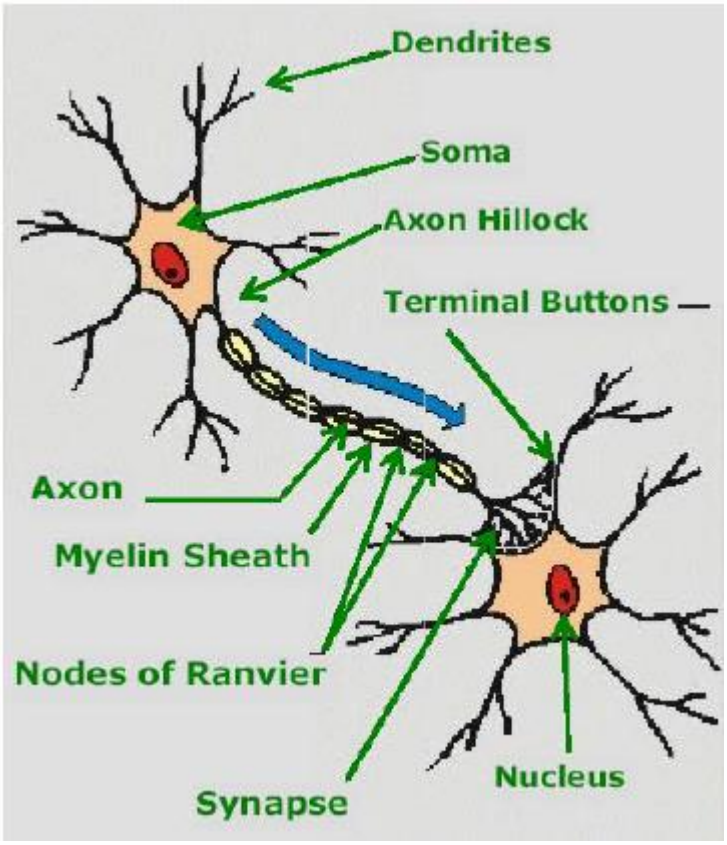


Fig: Structure of Neuron (Biological Neural Network)

Dendrites: are branching fibers that extend from the cell body or soma.

Soma or cell body of a neuron contains the nucleus and other structures, support chemical processing and production of neurotransmitters.

Axon: is singular fiber carries information away from the soma to the synaptic sites of other neurons (dendrites and somas), muscles, or glands.

Synapse: is the point of connection between two neurons or a neuron and a muscle or a gland. Electrochemical communication between neurons takes place at these junctions.

Axon hillock is the site of summation for incoming information. At any moment, the collective influence of all neurons that conduct impulses to a given neuron will determine whether or not an action potential will be initiated at the axon hillock and propagated along the axon.

Myelin Sheath consists of fat-containing cells that insulate the axon from electrical activity. This insulation acts to increase the rate of transmission of signals. A gap exists between each myelin sheath cell along the axon. Since fat inhibits the propagation of electricity, the signals jump from one gap to the next.

Nodes of Ranvier are the gaps (about 1 μm) between myelin sheath cells long axons are since fat serves as a good insulator, the myelin sheaths speed the rate of transmission of an electrical impulse along the axon.

Terminal Buttons of a neuron are the small knobs at the end of an axon that release chemicals called neurotransmitters.

2.3 Information flow in a Neural Cell

The input /output and the propagation of information are shown below.

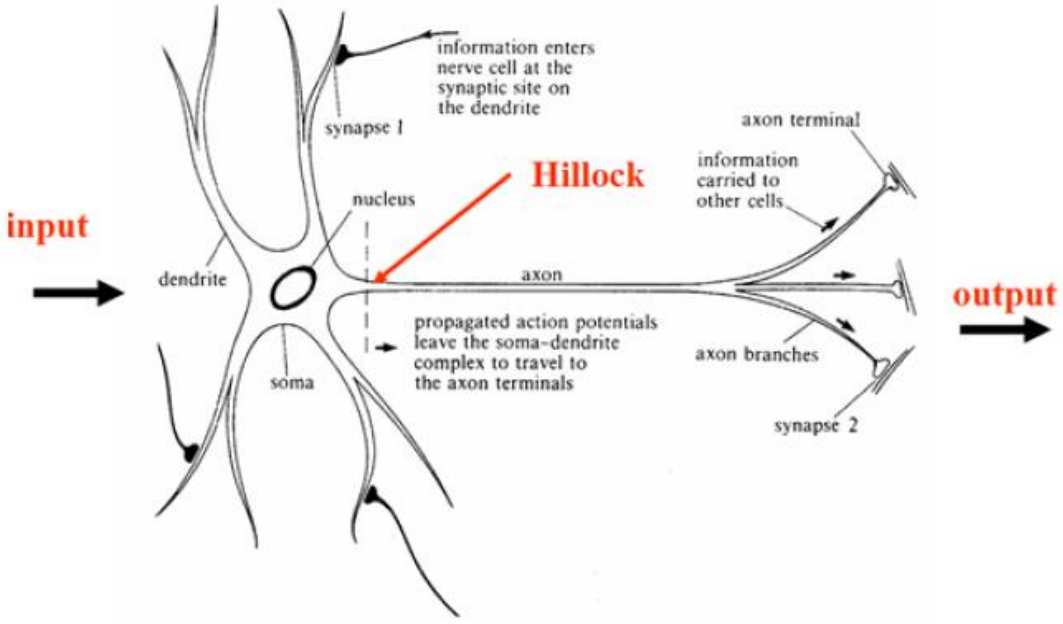


Fig. Structure of a neural cell in the human brain

- ***Dendrites*** *receive activation from other neurons.*
- ***Soma*** *processes the incoming activations and converts them into output activations.*
- ***Axons*** *act as transmission lines to send activation to other neurons.*
- ***Synapses*** *the junctions allow signal transmission between the axons and dendrites.*
- *The process of transmission is by diffusion of chemicals called* ***neuro-transmitters.***

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

2.4 Artificial Neural Networks (ANN)

An artificial neural network is an information processing system that has certain performance characters in common with biological neural networks. Artificial neural networks have been developed as generalizations of mathematical models of human cognition or neural biology, based on the assumptions that:-

1-Information processing occurs at many simple elements called neurons.
2-Signals are passed between neurons over connection links.
3-Each connection link has an associated weight which, in a typical neural net, multiplies the signal transmitted.
4-Each neuron applies an action function (usually nonlinear) to its net input (sum of weighted input signals) to determine its output signal.

2.5 Areas of Neural Networks (applications)

The areas in which neural networks are currently being applied are:

1-signal processing
2- Pattern Recognition (Examples: fingerprint image, handwritten word, human face).
3-control problems
4-medicine
5-speech production
6-speech Recognition
7-Business

2.6 Properties of Artificial Neural Networks

1-parallelism
2-capacity for adaptation "learning rather programming"
3-capacity of generalization
4-no problem definition
5- Abstraction & solving problem with noisy data.
6- Ease of constriction & learning.
7-Distributed memory
8- Fault tolerance

2.7 Neural Network Structure

An Artificial Neural Network (ANN) is a data processing system, consisting large number of *simple highly interconnected processing elements as artificial neuron in a network structure* that can be represented using a *directed graph* G, an ordered 2-tuple (V, E), consisting a set V of vertices and a set E of edges.

- The vertices may represent neurons (input/output)
- The edges may represent synaptic links labeled by the weights attached.

Example:

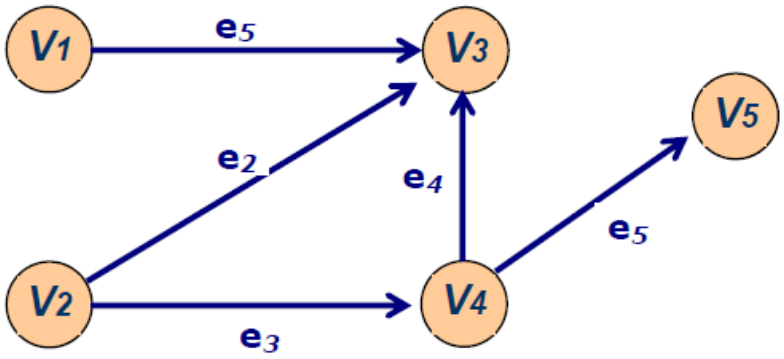
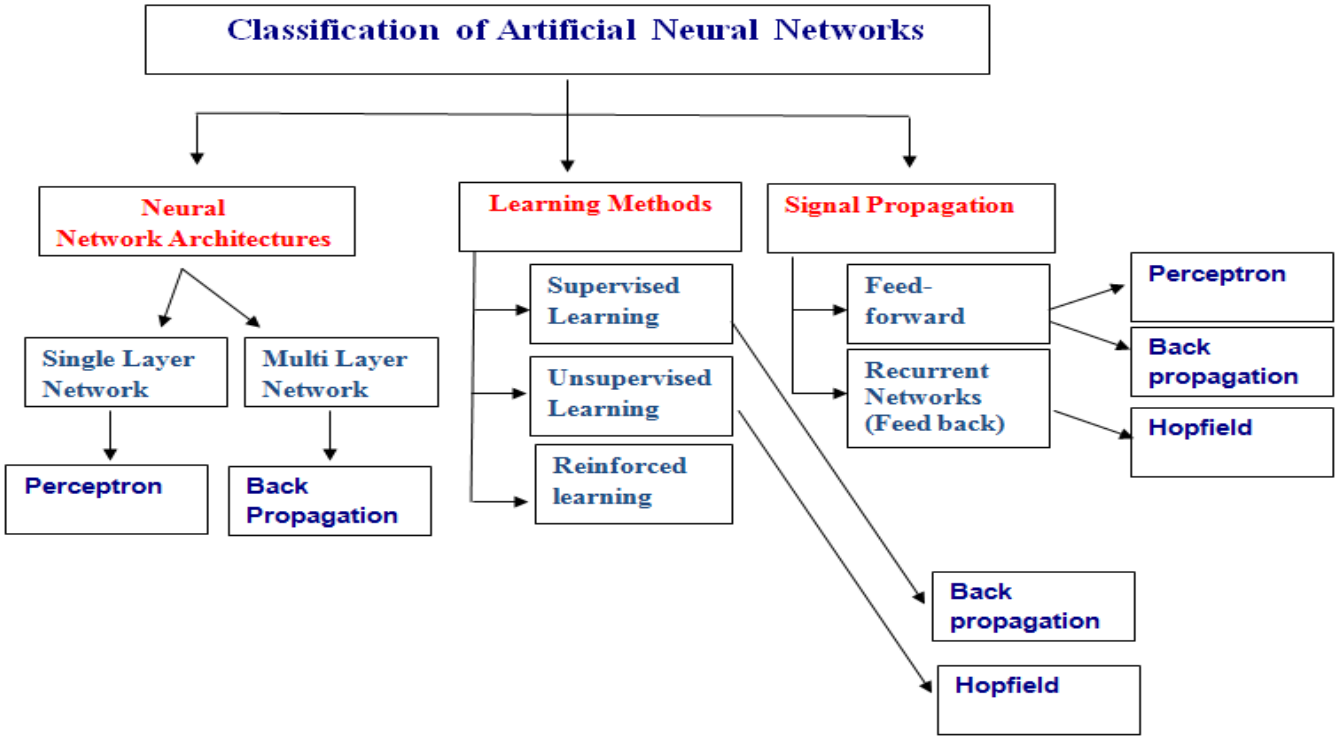


Fig. Directed Graph

Vertices $V = \{ v_1 , v_2 , v_3 , v_4, v_5 \}$

Edges $E = \{ e_1 , e_2 , e_3 , e_4, e_5 \}$


Classification of Artificial Neural Networks
Neural Network Architectures
Learning Methods
Signal Propagation
Single Layer Network
Multi Layer Network
Perceptron
Back Propagation
Supervised Learning
Unsupervised Learning
Reinforced learning
Feed-forward
Recurrent Networks (Feed back)
Perceptron
Back propagation
Hopfield
Back propagation
Hopfield

2.8 Single Layer Feed-forward Network

The Single Layer Feed-forward Network consists of a single layer of weights, where the inputs are directly connected to the outputs, via a series of weights. The synaptic links carrying weights connect every input to every output, but not other way. This way it is considered a network of feed-forward type.

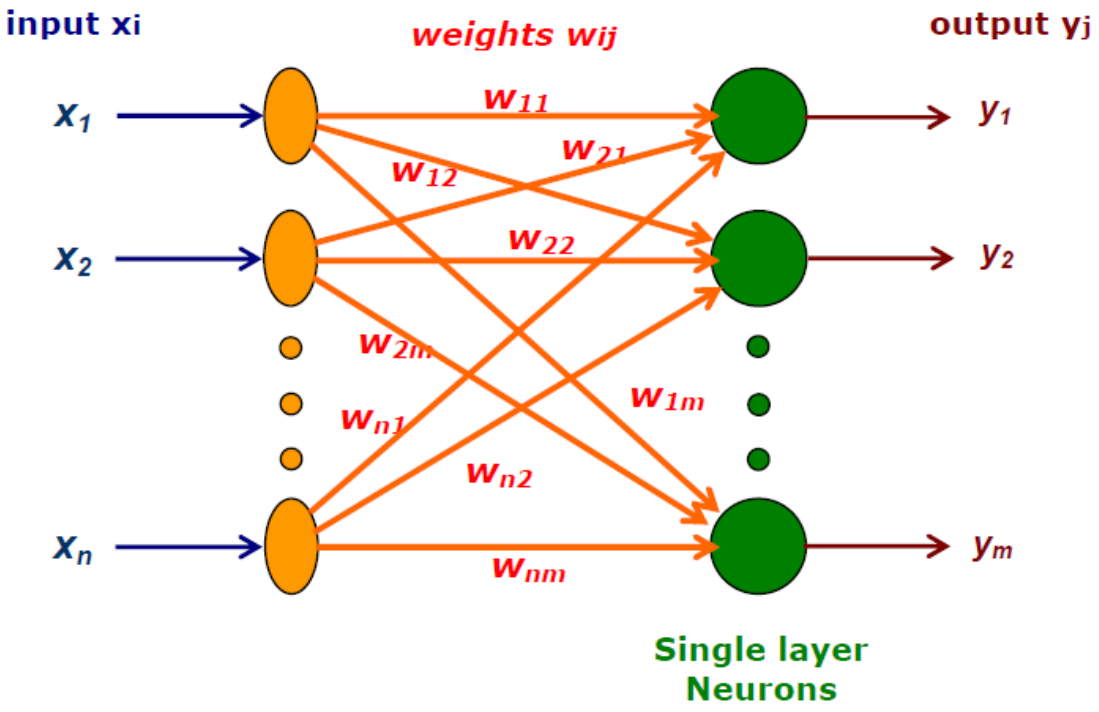


Fig. Single Layer Feed-forward Network

2.9 Multi Layer Feed-forward Network

The name suggests, it consists of multiple layers. The architecture of this class of network, besides having the input and the output layers, also have one or more intermediary layers called *hidden layers*. The computational units of the hidden layer are known as *hidden neurons.*

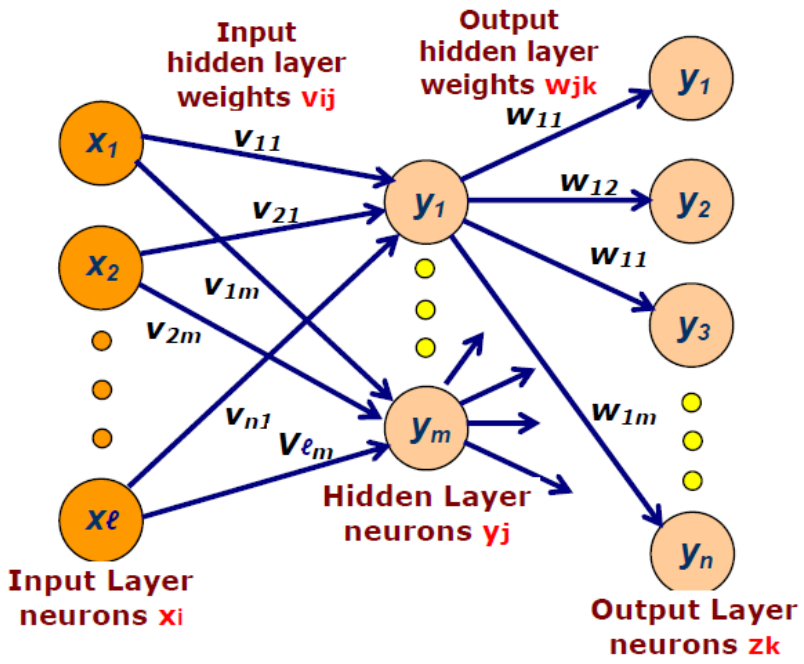


Fig. Multilayer feed-forward network in $(\ell - m - n)$ configuration.

2.10 Recurrent Networks

The Recurrent Networks differ from feed-forward architecture. A Recurrent network has *at* ***least one feedback loop.***

There could be neurons with self-feedback links; that is the output of a neuron is fed back into itself as input.

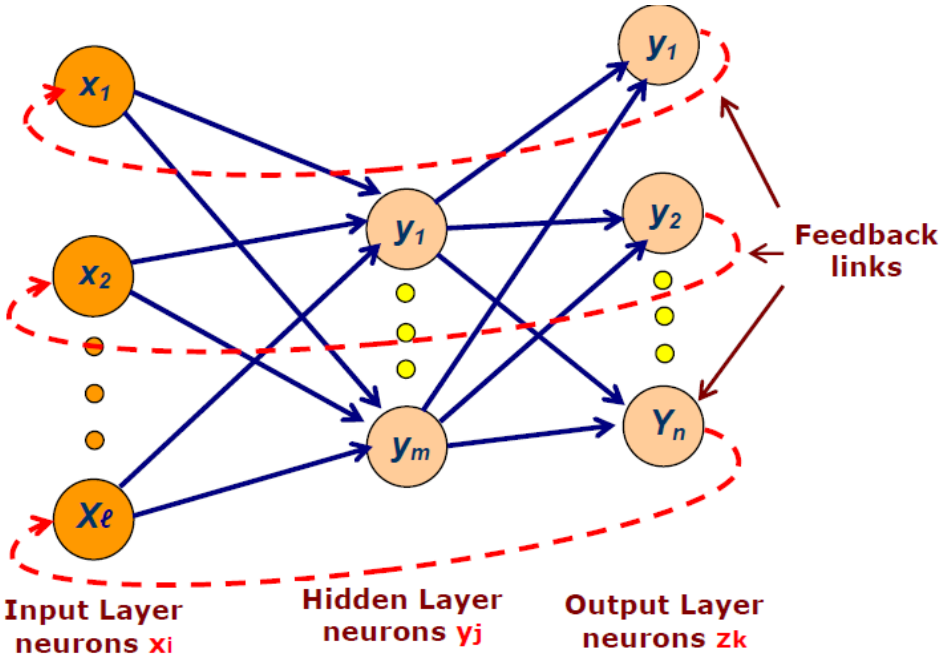


Fig Recurrent Neural Network

2.11 Learning Methods in Neural Networks (Classification of Learning Algorithms)

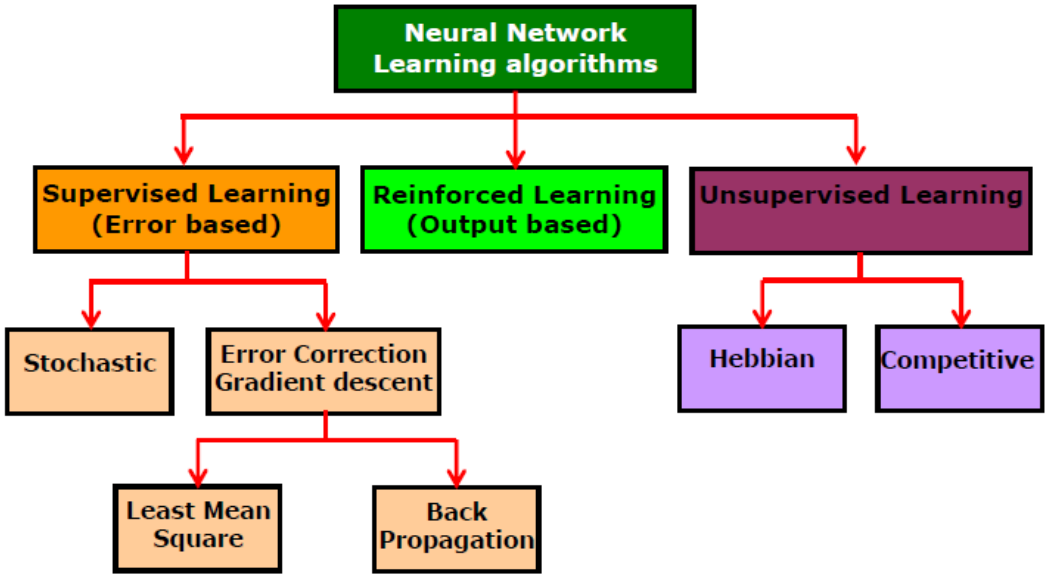


Fig. Classification of learning algorithms

The learning methods in neural networks are classified into three basic types:
- Supervised Learning,
- Unsupervised Learning and
- Reinforced Learning

These three types are classified based on:
- Presence or absence of teacher and
- The information provided for the system to learn.

These are further categorized, based on the rules used, as
- Hebbian,
- Gradient descent,
- Competitive and
- Stochastic learning.

Supervised Learning

- A teacher is present during learning process and presents expected output.
- Every input pattern is used to train the network.
- Learning process is based on comparison, between network's computed output and the correct expected output, generating "error".
- The "error" generated is used to change network parameters that result improved performance.

Unsupervised Learning

- No teacher is present.
- The expected or desired output is not presented to the network.
- The system learns of it own by discovering and adapting to the structural features in the input patterns.

Reinforced learning

- A teacher is present but does not present the expected or desired output but only indicated if the computed output is correct or incorrect.
- The information provided helps the network in its learning process.
- A reward is given for correct answer computed and a penalty for a wrong answer.

Note : The Supervised and Unsupervised learning methods are most popular forms of learning compared to Reinforced learning.

2.12 Classification of Neural Network

A taxonomy of neural network systems based on Architectural types and the learning methods is illustrated below.

		Learning Methods			
		Gradient descent	Hebbian	Competitive	Stochastic
Types of Architecture	Single-layer feed-forward	ADALINE, Hopfield, Percepton,	AM, Hopfield,	LVQ, SOFM	-
	Multi-layer feed- forward	CCM, MLFF, RBF	Neocognition		
	Recurrent Networks	RNN	BAM, BSB, Hopfield,	ART	Boltzmann and Cauchy machines

Table : Classification of Neural Network Systems with respect to learning methods and Architecture types

Taxonomy of Neural Network Systems:

– ADALINE (Adaptive Linear Neural Element)
– ART (Adaptive Resonance Theory)
– AM (Associative Memory)
– BAM (Bidirectional Associative Memory)
– Boltzmann machines
– BSB (Brain-State-in-a-Box)
– Cauchy machines
– Hopfield Network
– LVQ (Learning Vector Quantization)
– Neoconition
– Perceptron
– RBF (Radial Basis Function)
– RNN (Recurrent Neural Network)
– SOFM (Self-organizing Feature Map)

References : Textbooks

1. *"Neural Network, Fuzzy Logic, and Genetic Algorithms - Synthesis and Applications", by S. Rajasekaran and G.A. Vijayalaksmi Pai, (2005), Prentice Hall, Chapter 2, page 11-33.*
2. *"Soft Computing and Intelligent Systems Design - Theory, Tools and Applications",by Fakhreddine karray and Clarence de Silva (2004), Addison Wesley, chapter 4,page 223-248.*
3. *"Neural Networks: A Comprehensive Foundation", by Simon S. Haykin, (1999),Prentice Hall, Chapter 1-7, page 1-363.*
4. *"Elements of Artificial Neural Networks", by Kishan Mehrotra, Chilukuri K. Mohan and Sanjay Ranka, (1996), MIT Press, Chapter 1-5, page 1-214.*
5. *"Fundamentals of Neural Networks: Architecture, Algorithms and Applications", by Laurene V. Fausett, (1993), Prentice Hall, Chapter1-4, page 1-214.*
6. *"Neural Network Design", by Martin T. Hagan, Howard B. Demuth and Mark Hudson Beale, (1996) , PWS Publ. Company, Chapter 1-7, page 1-1 to 7-31.*
7. *"An Introduction to Neural Networks", by James A. Anderson, (1997), MIT Press,Chapter 1- 12, page 1-401.*
8. *Related documents from open source, mainly internet. An exhaustive list is being prepared for inclusion at a later date.*
9. http://www.myreaders.info/, RC *Chakraborty*