ARTIFICIAL NEURAL NETWORKS: AN INTRODUCTION

"Principles of Soft Computing, 2nd Edition"

by S.N. Sivanandam & SN Deepa

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DEFINITION OF NEURAL NETWORKS

According to the DARPA Neural Network Study (1988, AFCEA International Press, p. 60):

• ... a neural network is a system composed of many simple processing elements operating in parallel whose function is determined by network structure, connection strengths, and the processing performed at computing elements or nodes.

According to Haykin (1994), p. 2:

A neural network is a massively parallel distributed processor that has a natural propensity for storing experiential knowledge and making it available for use. It resembles the brain in two respects:

•Knowledge is acquired by the network through a learning process.

•Interneuron connection strengths known as synaptic weights are used to store the knowledge

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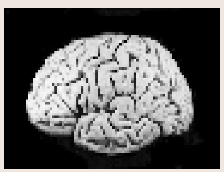
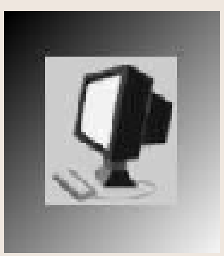
BRAIN COMPUTATION

The **human brain** contains about 10 billion nerve cells, or neurons. On average, each neuron is connected to other neurons through approximately 10,000 synapses.

	processing elements	element size	energy use	processing speed	style of computation	fault tolerant	learns	intelligent, conscious
	10^{14} synapses	10^{-6} m	30 W	100 Hz	parallel, distributed	yes	yes	usually
	10^{8} transistors	10^{-6} m	30 W (CPU)	10^{9} Hz	serial, centralized	no	a little	not (yet)

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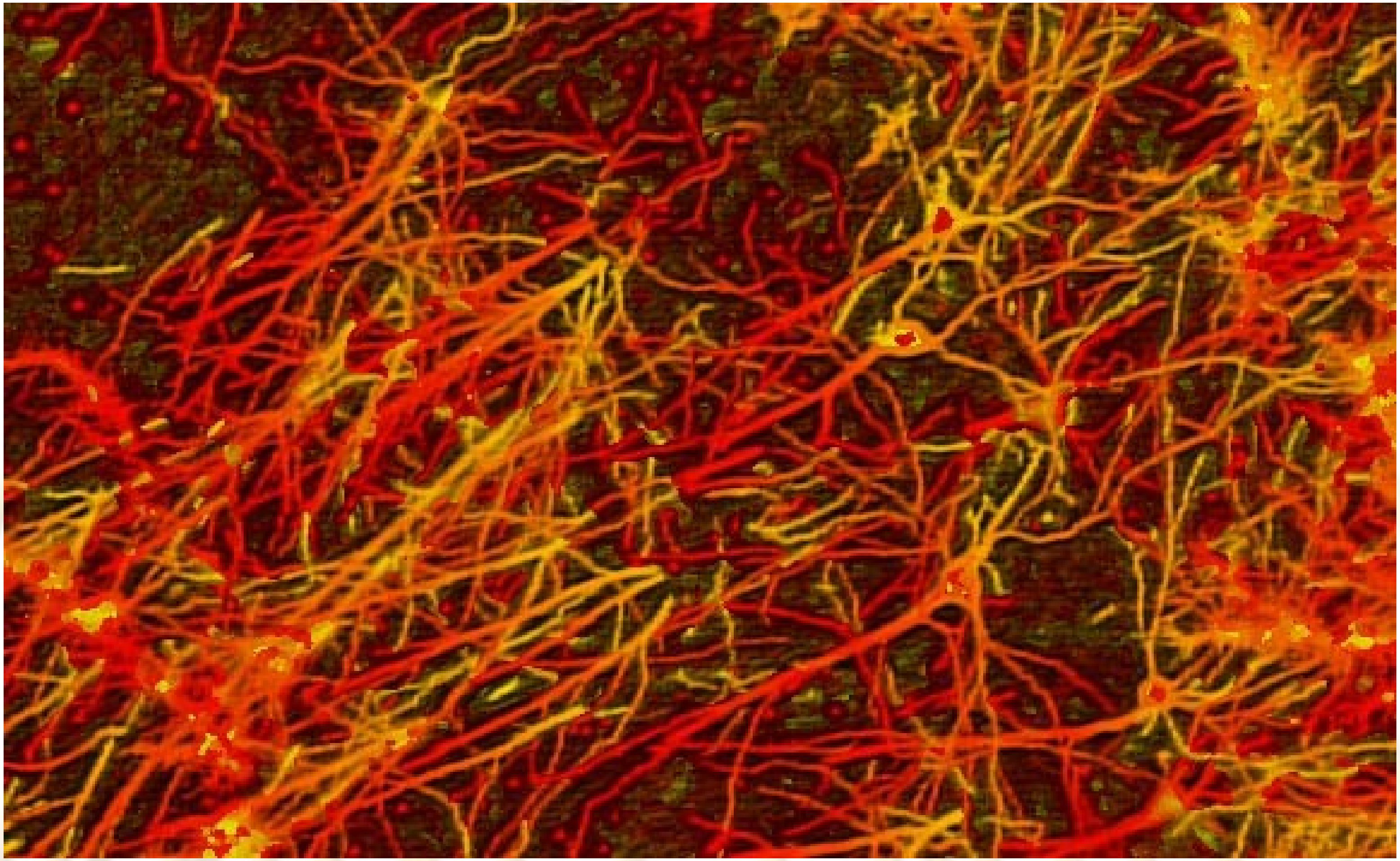
INTERCONNECTIONS IN BRAIN



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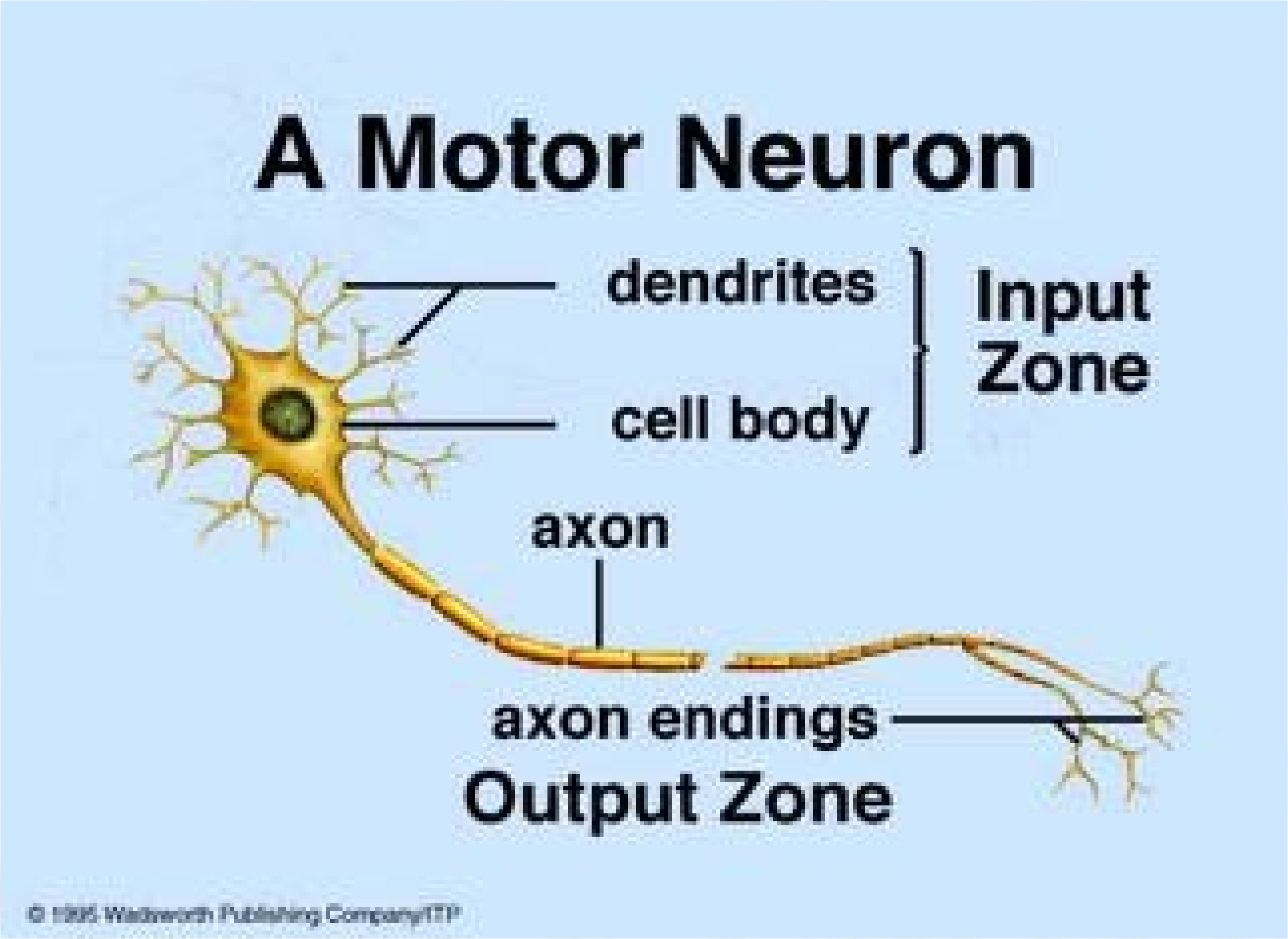
BIOLOGICAL (MOTOR) NEURON



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ARTIFICIAL NEURAL NET

- Information-processing system.
- Neurons process the information.
- The signals are transmitted by means of connection links.
- The links possess an associated weight.
- The output signal is obtained by applying activations to the net input.

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MOTIVATION FOR NEURAL NET

- Scientists are challenged to use machines more effectively for tasks currently solved by humans.
- Symbolic rules don't reflect processes actually used by humans.
- Traditional computing excels in many areas, but not in others.

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The major areas being:

- Massive parallelism
- Distributed representation and computation
- Learning ability
- Generalization ability
- Adaptivity
- Inherent contextual information processing
- Fault tolerance
- Low energy consumption.

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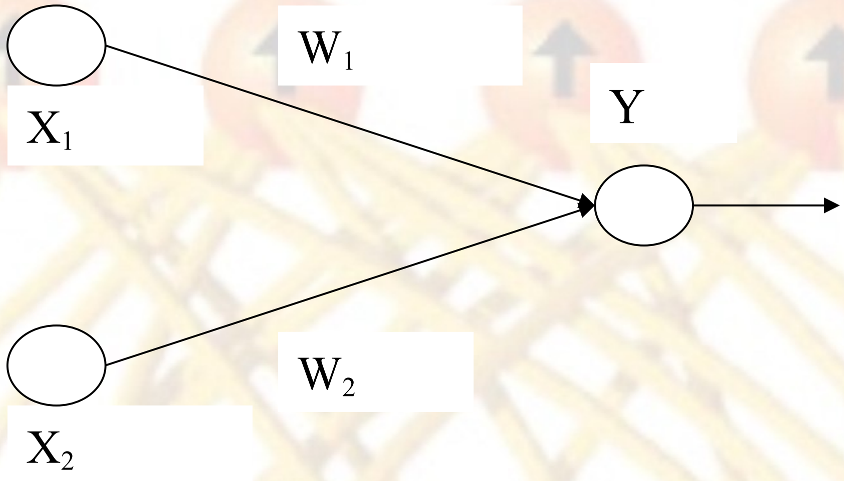
ARTIFICIAL NEURAL NET



The figure shows a simple artificial neural net with two input neurons (X_1, X_2) and one output neuron (Y). The inter connected weights are given by W_1 and W_2.

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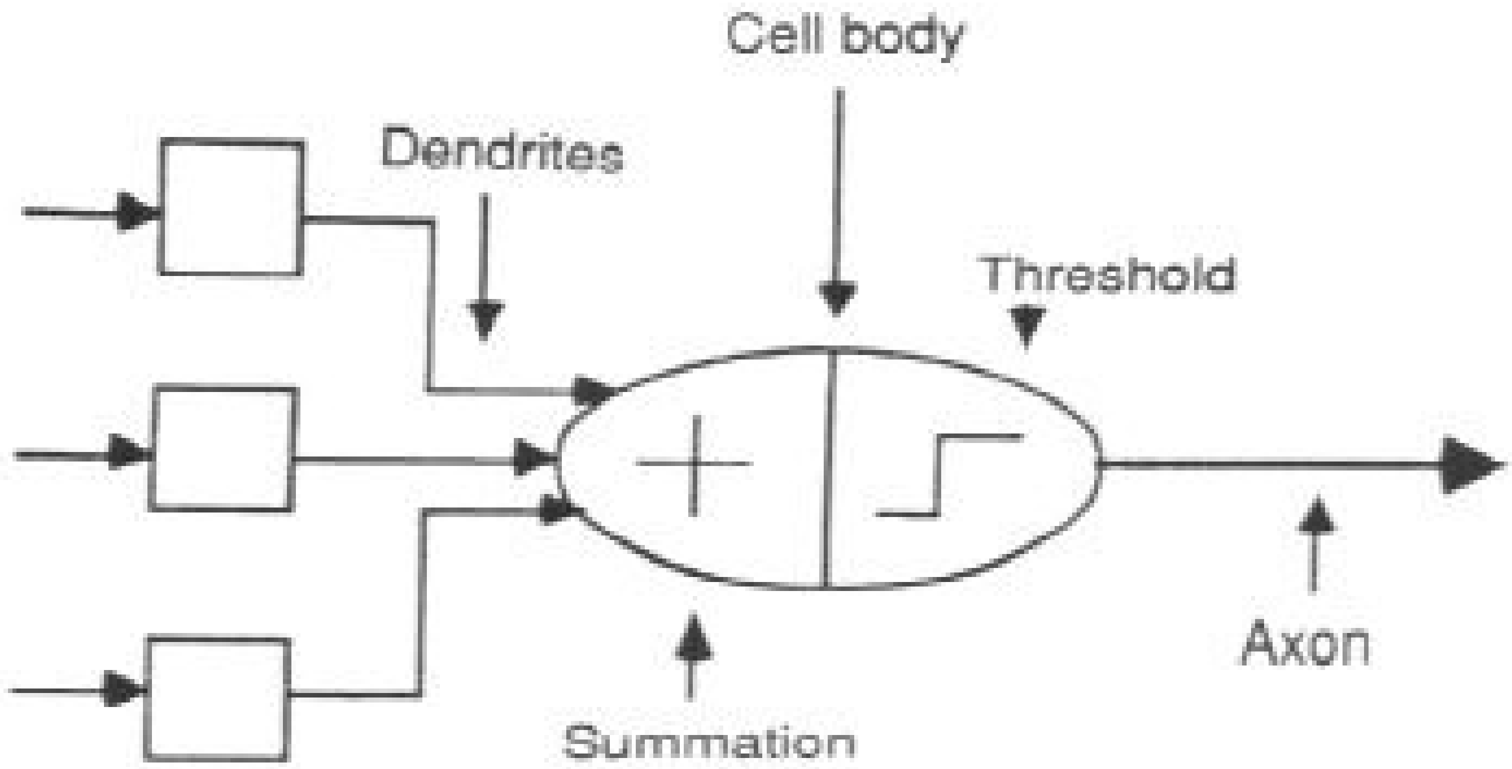
ASSOCIATION OF BIOLOGICAL NET WITH ARTIFICIAL NET



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PROCESSING OF AN ARTIFICIAL NET

The neuron is the basic information processing unit of a NN. It consists of:

1. A set of links, describing the neuron inputs, with weights $W_1, W_2, \ldots, W_m$.

2. An adder function (linear combiner) for computing the weighted sum of the inputs (real numbers):

$$u = \sum_{j=1}^{m} w_j x_j$$

3. Activation function for limiting the amplitude of the neuron output.

$$y = \varphi(u + b)$$

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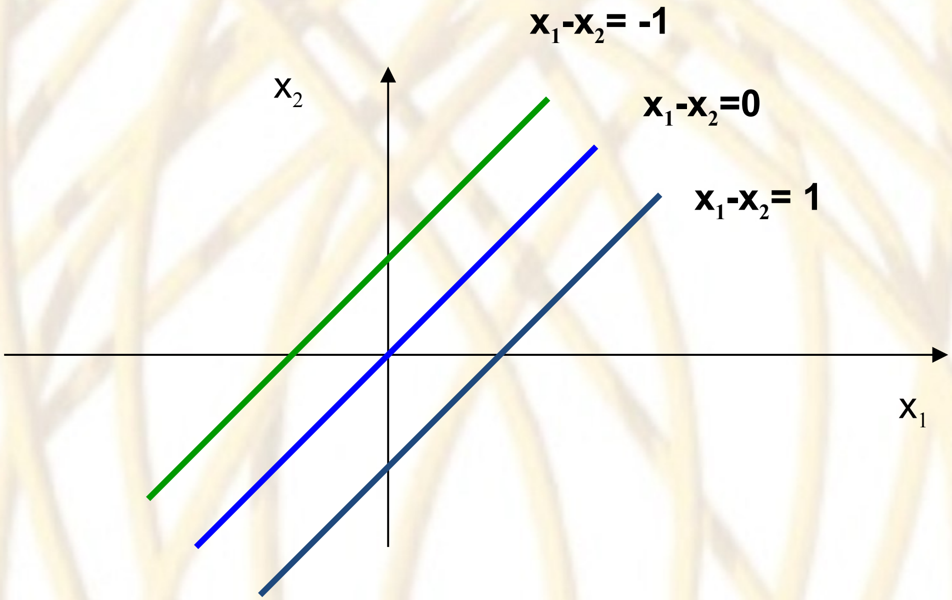
BIAS OF AN ARTIFICIAL NEURON

The bias value is added to the weighted sum

$\sum w_i x_i$ so that we can transform it from the origin.

$$Y_{in} = \sum w_i x_i + b, \text{ where } b \text{ is the bias}$$



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MULTI LAYER ARTIFICIAL NEURAL NET

INPUT: records without class attribute with normalized attributes values.

INPUT VECTOR: $X = \{ x_1, x_2, \ldots, x_n \}$ where n is the number of (non-class) attributes.

INPUT LAYER: there are as many nodes as non-class attributes, i.e. as the length of the input vector.

HIDDEN LAYER: the number of nodes in the hidden layer and the number of hidden layers depends on implementation.

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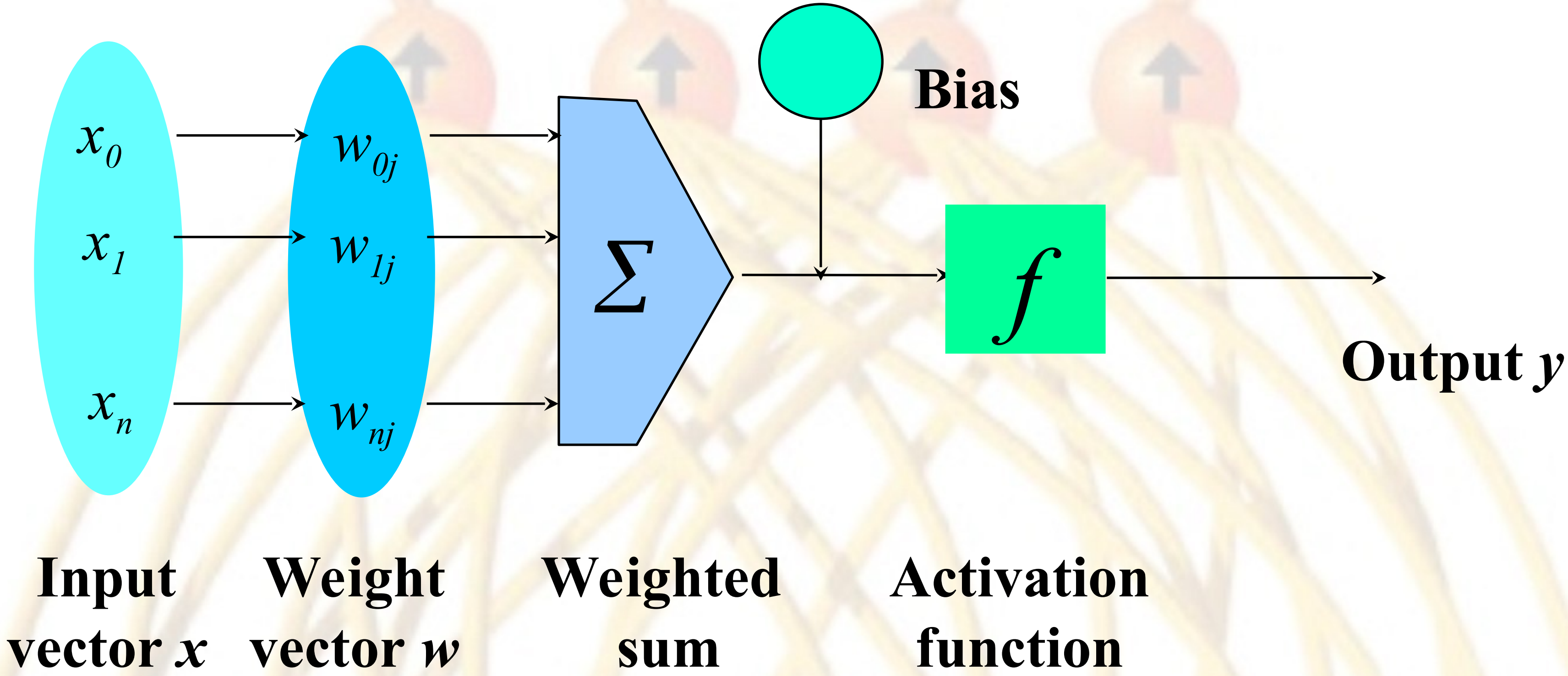
OPERATION OF A NEURAL NET



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WEIGHT AND BIAS UPDATION

Per Sample Updating

•updating weights and biases after the presentation of each sample.

Per Training Set Updating (Epoch or Iteration)

•weight and bias increments could be accumulated in variables and the weights and biases updated after all the samples of the training set have been presented.

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STOPPING CONDITION

- All change in weights (Δwij) in the previous epoch are below some threshold, or
- The percentage of samples misclassified in the previous epoch is below some threshold, or
- A pre-specified number of epochs has expired.
- In practice, several hundreds of thousands of epochs may be required before the weights will converge.

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BUILDING BLOCKS OF ARTIFICIAL NEURAL NET

- Network Architecture (Connection between Neurons)
- Setting the Weights (Training)
- Activation Function

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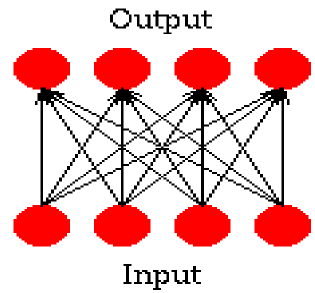
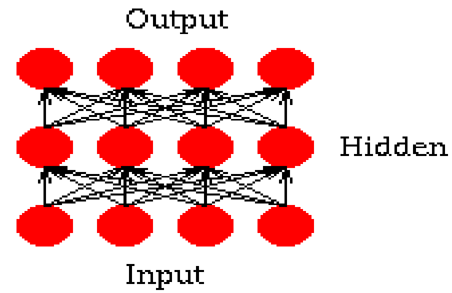
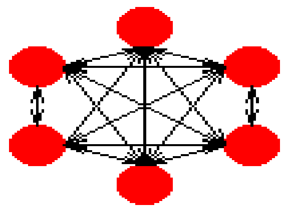


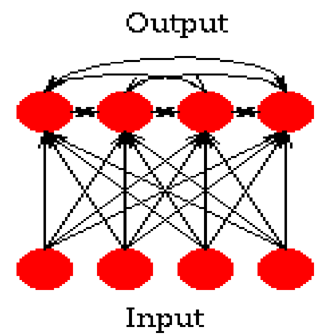
Single Layer Feedforward



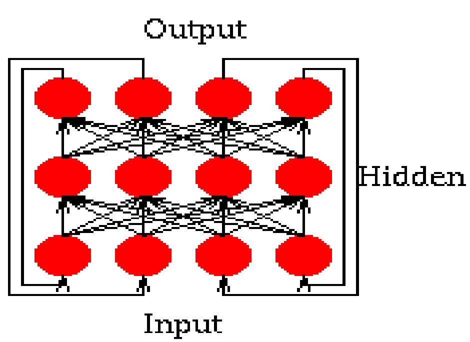
Multi Layer Feedforward



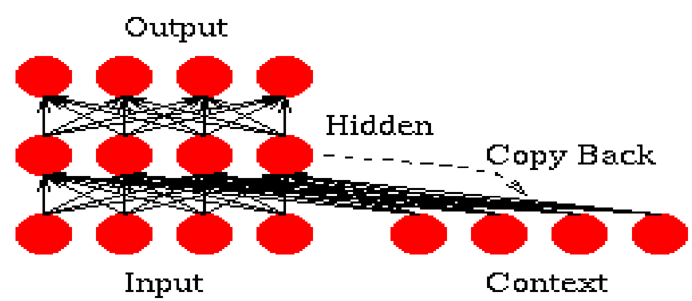
Fully Recurrent Network



Competitive Network



Jordan Network



Simple Recurrent Network

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LAYER PROPERTIES

- **Input Layer:** Each input unit may be designated by an attribute value possessed by the instance.

- **Hidden Layer:** Not directly observable, provides nonlinearities for the network.

- **Output Layer:** Encodes possible values.

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TRAINING PROCESS

- **Supervised Training** - Providing the network with a series of sample inputs and comparing the output with the expected responses.

- **Unsupervised Training** - Most similar input vector is assigned to the same output unit.

- **Reinforcement Training** - Right answer is not provided but indication of whether 'right' or 'wrong' is provided.

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ACTIVATION FUNCTION

- **ACTIVATION LEVEL – DISCRETE OR CONTINUOUS**

- **HARD LIMIT FUCNTION (DISCRETE)**
  - Binary Activation function
  - Bipolar activation function
  - Identity function

- **SIGMOIDAL ACTIVATION FUNCTION (CONTINUOUS)**
  - Binary Sigmoidal activation function
  - Bipolar Sigmoidal activation function

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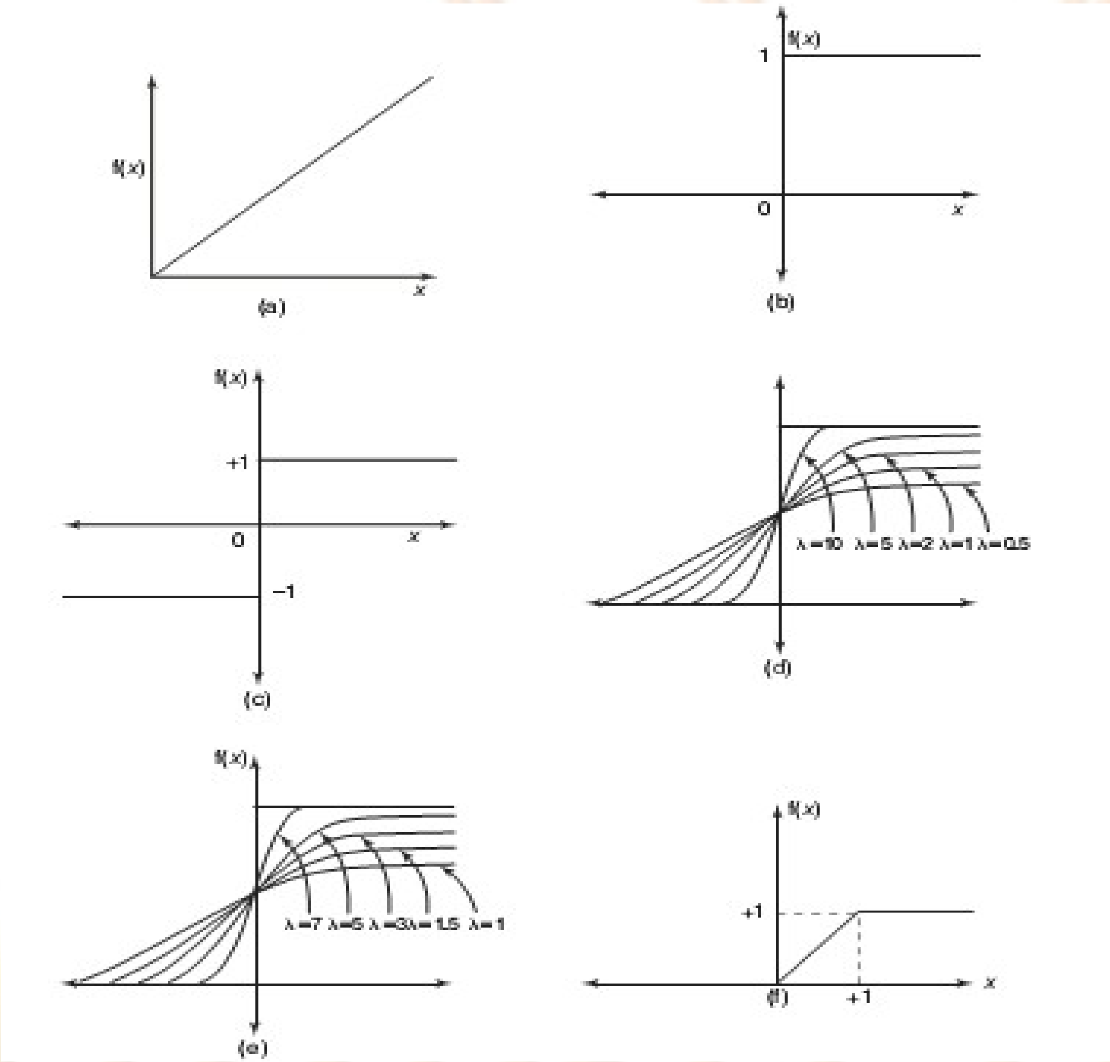
ACTIVATION FUNCTION



Activation functions:

(A) Identity

(B) Binary step

(C) Bipolar step

(D) Binary sigmoidal

(E) Bipolar sigmoidal

(F) Ramp

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CONSTRUCTING ANN

- Determine the network properties:
  - Network topology
  - Types of connectivity
  - Order of connections
  - Weight range

- Determine the node properties:
  - Activation range

- Determine the system dynamics
  - Weight initialization scheme
  - Activation – calculating formula
  - Learning rule

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PROBLEM SOLVING

- Select a suitable NN model based on the nature of the problem.
- Construct a NN according to the characteristics of the application domain.
- Train the neural network with the learning procedure of the selected model.
- Use the trained network for making inference or solving problems.

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NEURAL NETWORKS

- **Neural Network** learns by adjusting the weights so as to be able to correctly classify the training data and hence, after testing phase, to classify unknown data.

- **Neural Network** needs long time for training.

- **Neural Network** has a high tolerance to noisy and incomplete data.

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McCULLOCH–PITTS NEURON

- Neurons are sparsely and randomly connected
- Firing state is binary (1 = firing, 0 = not firing)
- All but one neuron are excitatory (tend to increase voltage of other cells)
  - One inhibitory neuron connects to all other neurons
  - It functions to regulate network activity (prevent too many firings)

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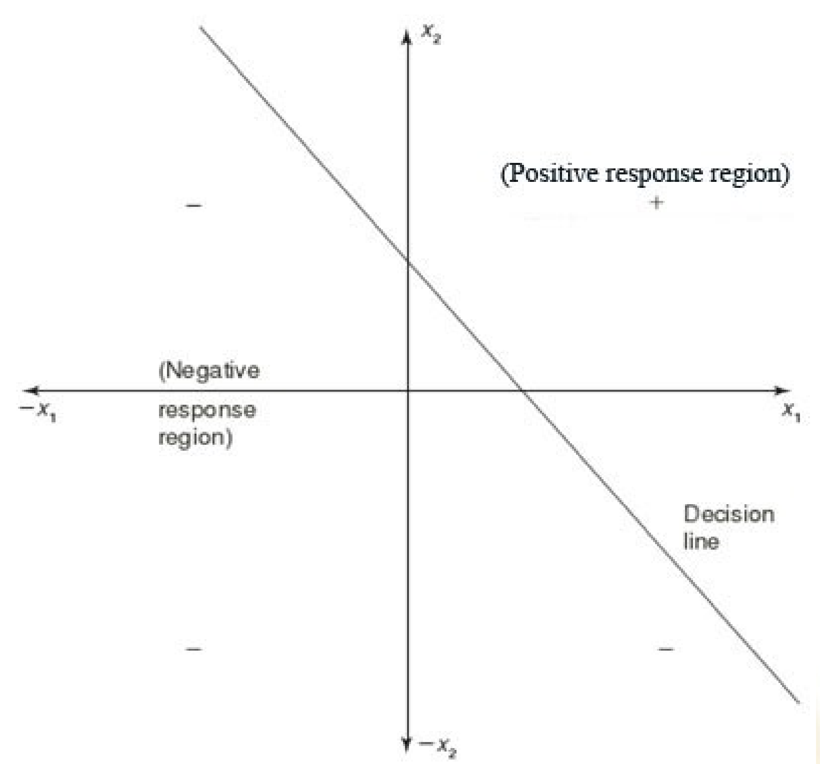
LINEAR SEPARABILITY

- Linear separability is the concept wherein the separation of the input space into regions is based on whether the network response is positive or negative.

- Consider a network having positive response in the first quadrant and negative response in all other quadrants (AND function) with either binary or bipolar data, then the decision line is drawn separating the positive response region from the negative response region.



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HEBB NETWORK

Donald Hebb stated in 1949 that in the brain, the learning is performed by the change in the synaptic gap. Hebb explained it:

“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 takes place in one or both the cells such that A’s efficiency, as one of the cells firing B, is increased.”

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HEBB LEARNING

- The weights between neurons whose activities are positively correlated are increased:

$$\frac{dw_{ij}}{dt} \sim \text{correlation}(x_i, x_j)$$

- Associative memory is produced automatically

- The Hebb rule can be used for pattern association, pattern categorization, pattern classification and over a range of other areas.

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FEW APPLICATIONS OF NEURAL NETWORKS

- Aerospace
- Automotive
- Banking
- Credit Card Activity Checking
- Defense
- Electronics
- Entertainment
- Financial
- Industrial
- Insurance
- Insurance
- Manufacturing
- Medical
- Oil and Gas
- Robotics
- Speech
- Securities
- Telecommunications
- Transportation

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