ANN Architecture

ANN Architecture

- ANN posess a large number of processing elements called nodes/neurons which operate in parallel.
- Neurons are connected with others by connection link.
- Each link is associated with weights which contain information about the input signal.
- Each neuron has an internal state of its own which is a function of the inputs that neuron receives- Activation level

Neuron Modeling for ANN

$o = f(\mathbf{w}^t\mathbf{x})$, or

$$o = f\left(\sum_{i=1}^{n} w_i x_i\right)$$

Is referred to activation function. Domain is set of activation values *net.*

$$net \triangleq \mathbf{w}^t\mathbf{x}$$

Scalar product of weight and input vector

Neuron as a processing node performs the operation of summation of its weighted input.

Activation function

- Bipolar binary and unipolar binary are called as hard limiting activation functions used in discrete neuron model
- Unipolar continuous and bipolar continuous are called soft limiting activation functions are called sigmoidal characteristics.

Activation functions

Bipolar continuous

$$f(net) \triangleq \frac{2}{1 + \exp(-\lambda net)} - 1$$

$$\lambda > 0$$

$$f(net) \triangleq \operatorname{sgn}(net) = \begin{cases} +1, & net > 0 \\ -1, & net < 0 \end{cases}$$

Bipolar binary functions

Activation functions

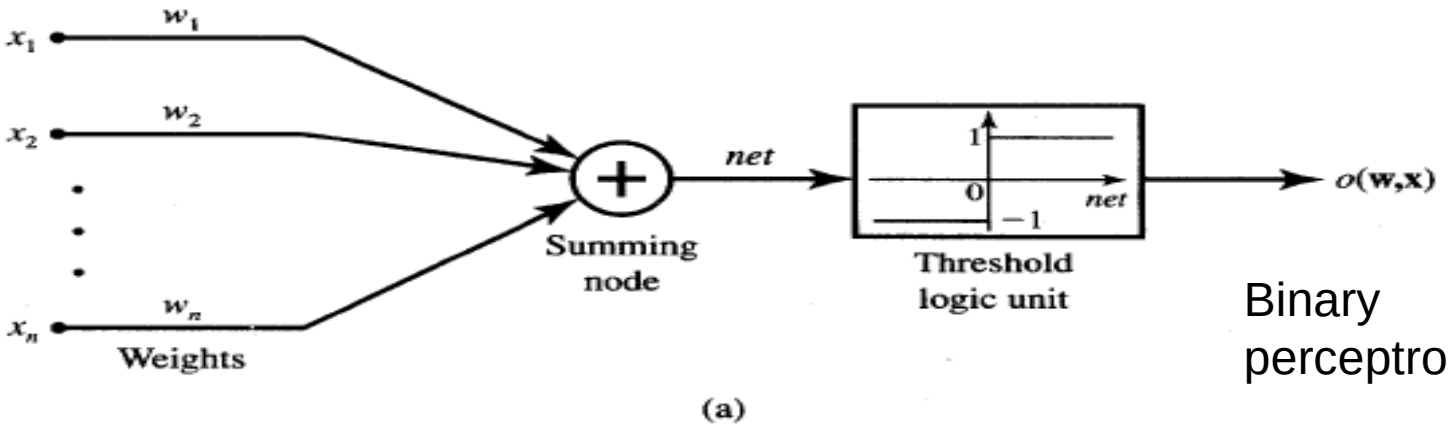
Unipolar continuous

$$f(net) \triangleq \frac{1}{1 + \exp(-\lambda net)}$$

Unipolar Binary

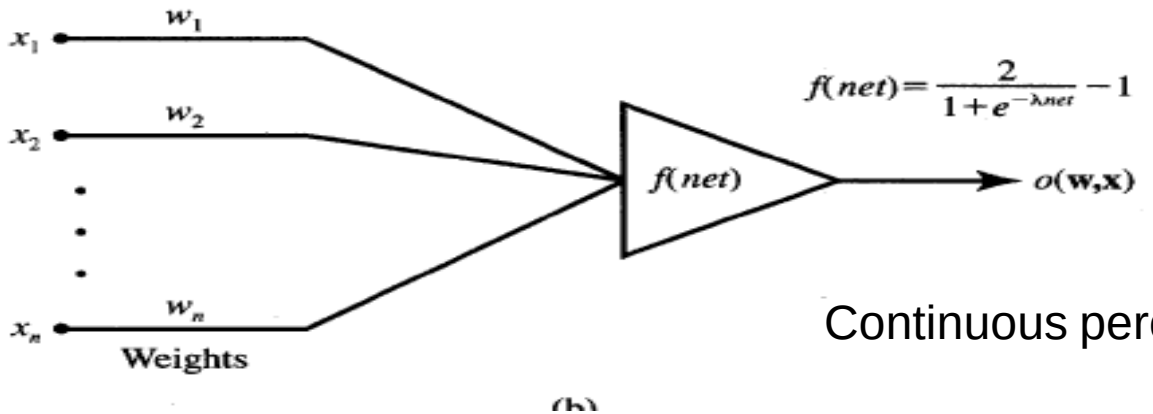
$$f(net) \triangleq \begin{cases} 1, & net > 0 \\ 0, & net < 0 \end{cases}$$

Common models of neurons



Binary perceptrons

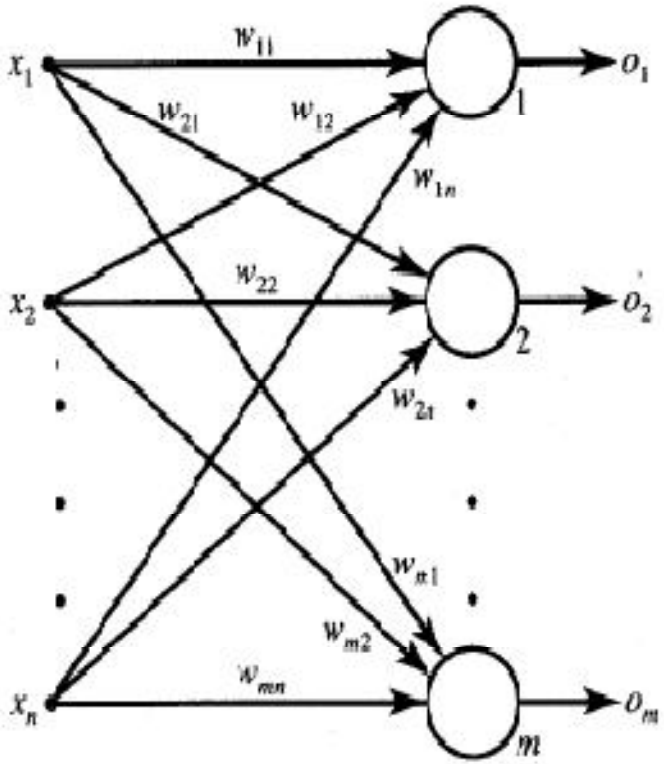
(a)

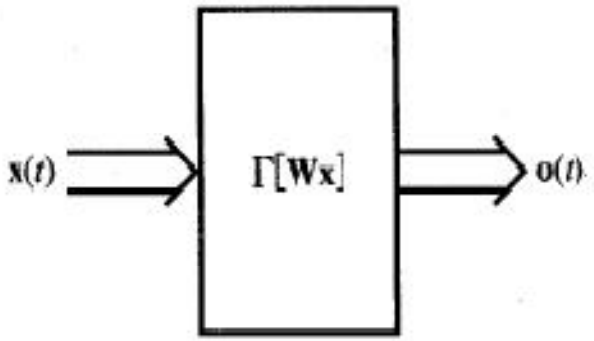


Continuous perceptrons

(b)

Single layer Feedforward Network





Feedforward Network

- Its output and input vectors are respectively

$$\mathbf{o} = [o_1 \quad o_2 \quad \cdots \quad o_m]^t$$
$$\mathbf{x} = [x_1 \quad x_2 \quad \cdots \quad x_n]^t$$

- Weight w_{ij} connects the *i'th* neuron with *j'th* input. Activation rule of ith neuron is

$$net_i = \sum_{j=1}^{n} w_{ij} x_j, \quad \text{for } i = 1, 2, \ldots, m$$

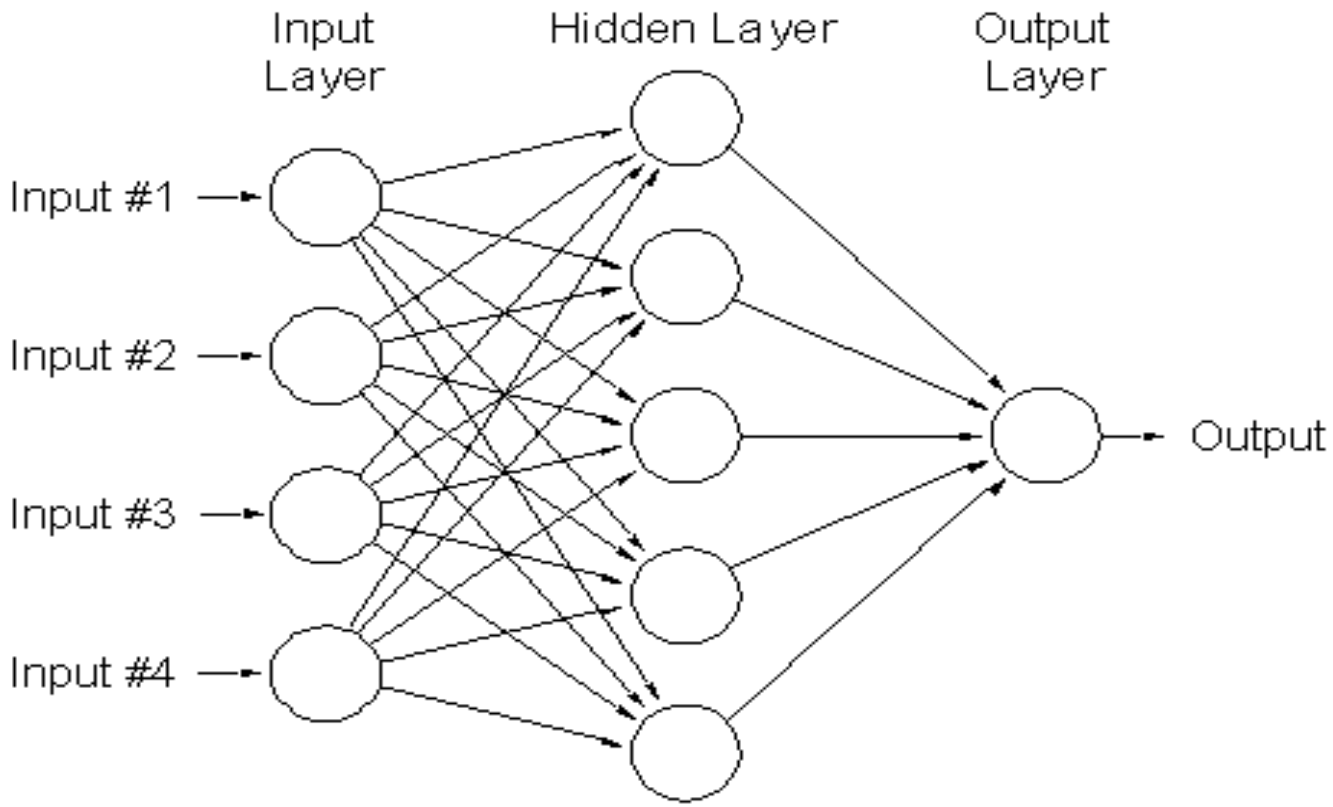
$$o_i = f(\mathbf{w}_i^t \mathbf{x}), \quad \text{for } i = 1, 2, \ldots, m$$

where

$$\mathbf{w}_i \triangleq [w_{i1} \quad w_{i2} \quad \cdots \quad w_{in}]^t$$

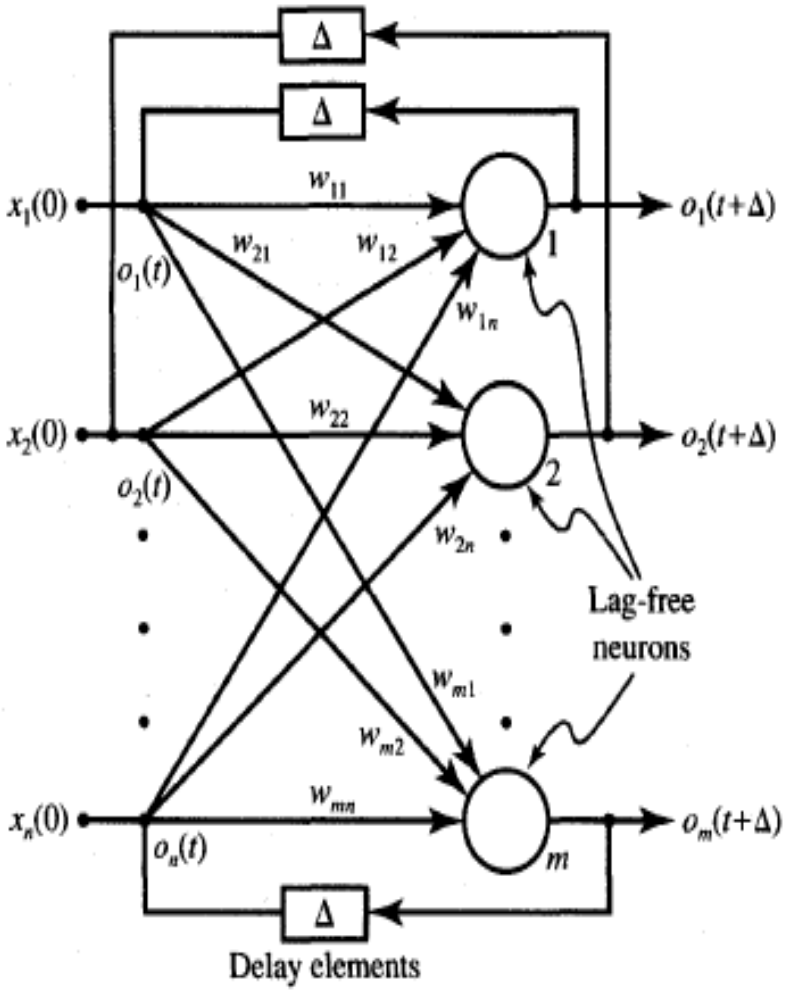
EXAMPLE

Multilayer feed forward network

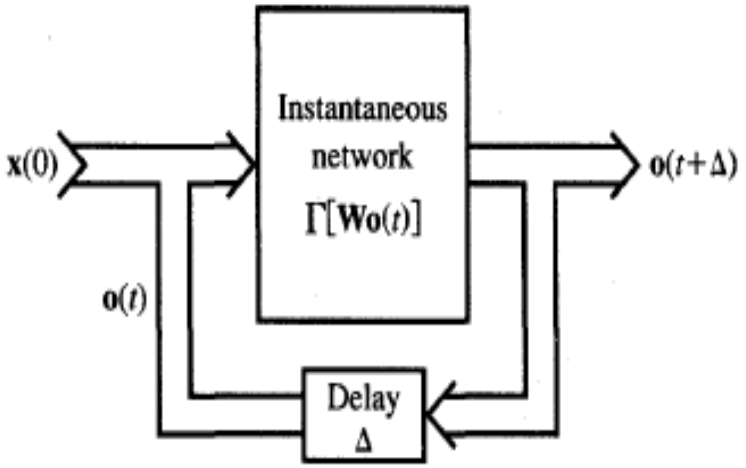


Can be used to solve complicated problems

Feedback network



When outputs are directed back as inputs to same or preceding layer nodes it results in the formation of feedback networks



Activation Function

1. Identity Function
   f(x)=x for all x
2. Binary Step function

$$f(x) = \begin{cases} 1 if x \geq \theta \\ 0 if x < \theta \end{cases}$$

3. Bipolar Step function

$$f(x) = \begin{cases} 1 if x \geq \theta \\ -1 if x < \theta \end{cases}$$

4. Sigmoidal Functions:- Continuous functions
5. Ramp functions:-

$$f(x) = \begin{cases} 1 if x > 1 \\ x if\ 0 \leq x \leq 1 \\ 0 if x < 0 \end{cases}$$

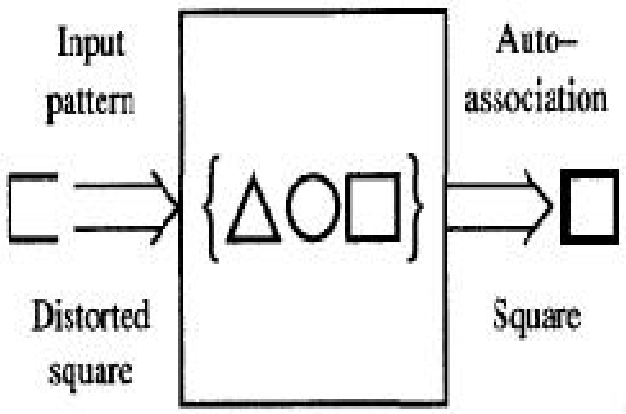
Some learning algorithms

- Supervised:
  - Adaline, Madaline
  - Perceptron
  - Back Propagation
  - multilayer perceptrons
  - Radial Basis Function Networks
- Unsupervised
  - Competitive Learning
  - Kohenen self organizing map
  - Learning vector quantization
  - Hebbian learning

Neural processing

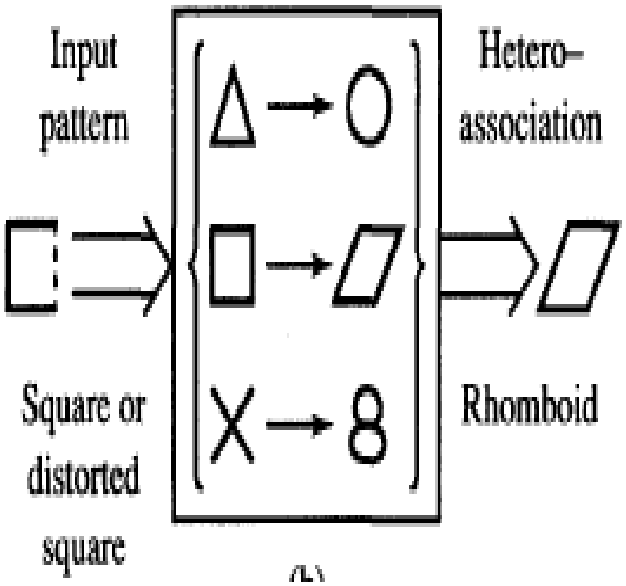
- **Recall:**- processing phase for a NN and its objective is to retrieve the information. The process of computing **o** for a given **x**
- **Basic forms of neural information processing**
  - Auto association
  - Hetero association
  - Classification

Neural processing-Autoassociation



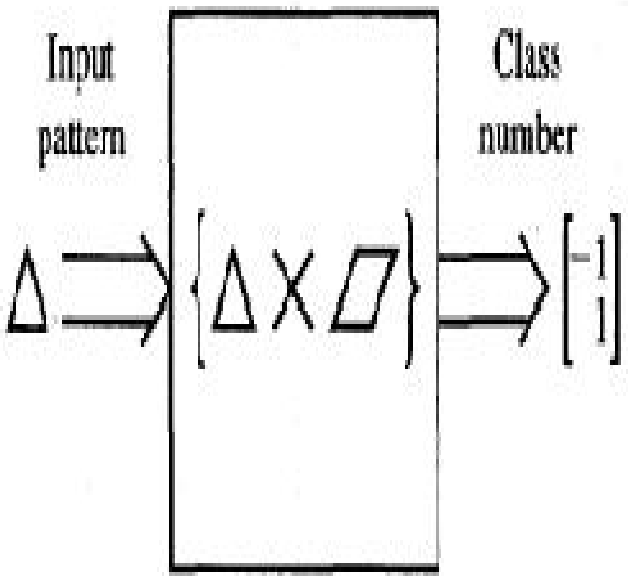
- Set of patterns can be stored in the network
- If a pattern similar to a member of the stored set is presented, an association with the input of closest stored pattern is made

Neural Processing- Heteroassociation



- Associations between pairs of patterns are stored
- Distorted input pattern may cause correct heteroassociation at the output

Neural processing-Classification



- Set of input patterns is divided into a number of classes or categories
- In response to an input pattern from the set, the classifier is supposed to recall the information regarding class membership of the input pattern.

Important terminologies of ANNs

- Weights
- Bias
- Threshold
- Learning rate
- Momentum factor
- Vigilance parameter
- Notations used in ANN

Weights

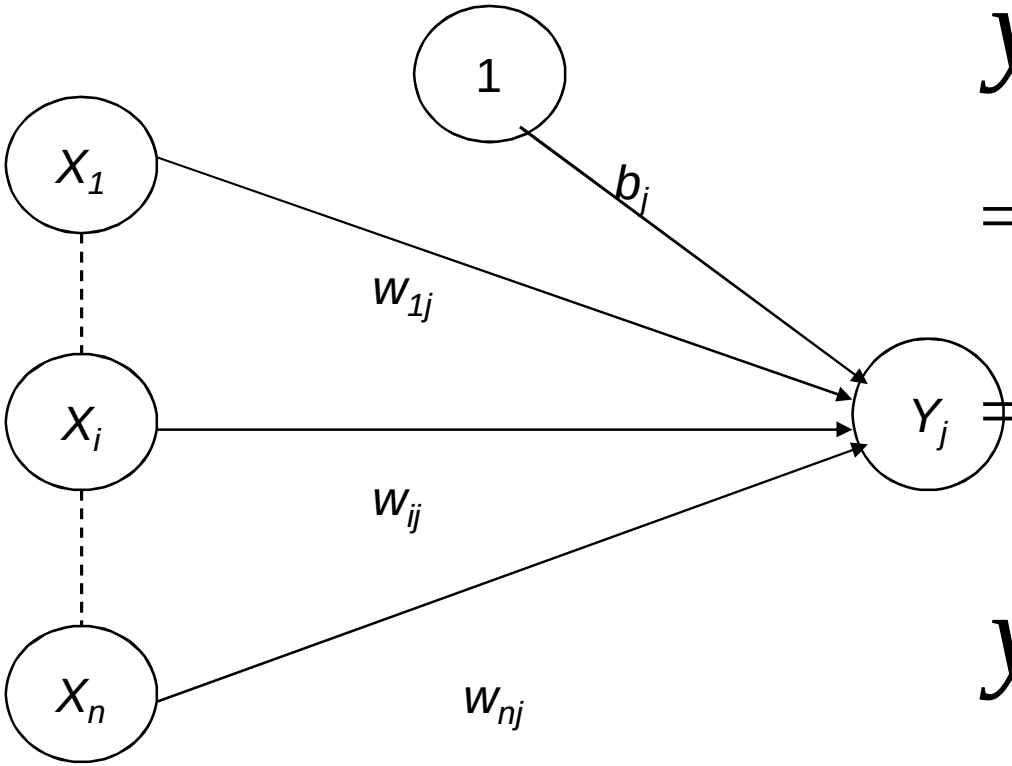
- Each neuron is connected to every other neuron by means of directed links
- Links are associated with weights
- Weights contain information about the input signal and is represented as a matrix
- Weight matrix also called connection matrix

Weight matrix

$$W = \begin{bmatrix} w_1^T \\ w_2^T \\ w_3^T \\ . \\ . \\ . \\ . \\ . \\ w_n^T \end{bmatrix} = \begin{bmatrix} w_{11} w_{12} w_{13} \cdots w_{1m} \\ w_{21} w_{22} w_{23} \cdots w_{2m} \\ \cdots\cdots\cdots\cdots\cdots \\ \cdots\cdots\cdots\cdots\cdots \\ w_{n1} w_{n2} w_{n3} \cdots w_{nm} \end{bmatrix}$$

Weights contd…

- w_{ij} _is the weight from processing element *"i"* (source node) to processing element *"j"* (destination node)



$$y_{inj} = \sum_{i=0}^{n} x_i w_{ij}$$

$$= x_0 w_{0j} + x_1 w_{1j} + x_2 w_{2j} + ... + x_n w_{nj}$$

$$= w_{0j} + \sum_{i=1}^{n} x_i w_{ij}$$

$$y_{inj} = b_j + \sum_{i=1}^{n} x_i w_{ij}$$

Activation Functions

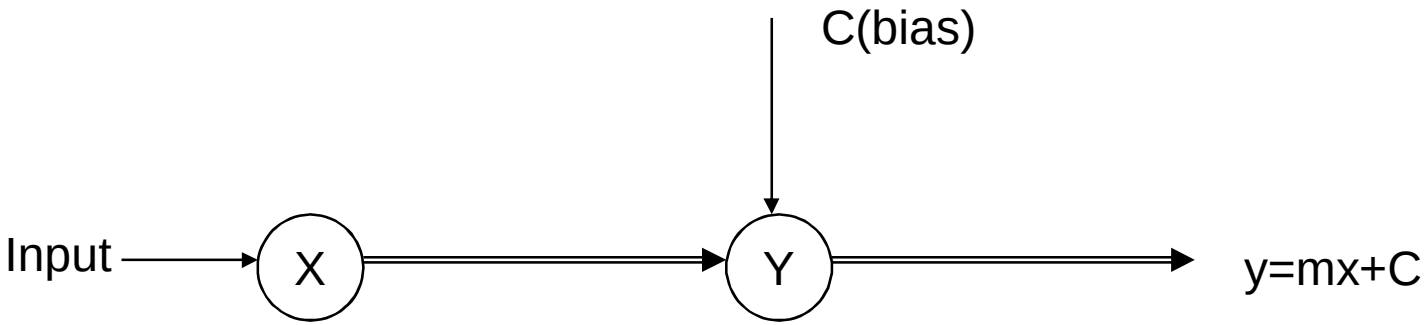
- Used to calculate the output response of a neuron.
- Sum of the weighted input signal is applied with an activation to obtain the response.
- Activation functions can be linear or non linear
- Already dealt
  - Identity function
  - Single/binary step function
  - Discrete/continuous sigmoidal function.

Bias

- Bias is like another weight. Its included by adding a component $x_0=1$ to the input vector X.
- $X=(1,X_1,X_2 \ldots X_i,\ldots X_n)$
- Bias is of two types
  - Positive bias: increase the net input
  - Negative bias: decrease the net input

Why Bias is required?

- The relationship between input and output given by the equation of straight line y=mx+c



Threshold

- Set value based upon which the final output of the network may be calculated
- Used in activation function
- The activation function using threshold can be defined as

$$f(net) = \begin{Bmatrix} 1 if net \geq \theta \\ -1 if net < \theta \end{Bmatrix}$$

Learning rate

- Denoted by α.
- Used to control the amount of weight adjustment at each step of training
- Learning rate ranging from 0 to 1 determines the rate of learning in each time step

Other terminologies

- Momentum factor:
  - used for convergence when momentum factor is added to weight updation process.
- Vigilance parameter:
  - Denoted by ρ
  - Used to control the degree of similarity required for patterns to be assigned to the same cluster