Unit-1 (Part-1)

Application of Soft Computing

Soft Computing: Soft Computing is defined as a multidisciplinary system which is a combination of Neural Network (NN), Fuzzy Logic (FL) and genetic algorithms (GA).

> Soft Computing (SC) = NN + FL + GA

Fuzzy Logic for knowledge representation
Neural Network for learning and
Genetic Algorithm for Evaluationary computation.

OR

Soft Computing is the fusion of methodologies designed to model and enable solutions to real world problems which are not modeled or too difficult to model mathematically.

Goals of Soft Computing: Soft Computing is used to construct new generation of artificial Intelligence known as computation intelligence.

1. The main goal is to develop intelligent machine which are not modeled / difficult to model mathematically
2. The aim is to exploit the tolerance for approximation (model feature are similar to real one, but not the same), Uncertainty (we are not sure that the features of the model are the same as that of the entity), Imprecision (model features (quantities) are not the same as that of real ones, but close to them) and partial truth

in order to achieve close resemblance with human like decision making.

Application of soft Computing

1. Consumer appliance like AC, Refrigerator, Heaters, Washing machine.
2. Robotics work in the form of emotional Pet robots.
3. Food preparation devices (e.g. Microwave & Rice Cookers)
4. for amusing gaming playing product like Checker and poker etc.
5. Recognition for handwritten.
6. Data Compression / image processing.
7. Power System analysis
8. Decision Support System.
9. Bioinformatics
10. Investment and trading.
11. Automotive Systems and manufacturing.
12. Image Processing

Difference between Conventional (Hard) Computing and Soft Computing :

Conventional (Hard) Computing	Soft Computing
① Requires program to be written	① Can evolve its own program.
② It can only deal with exact data.	② It can deal with ambiguous and noisy data.
③ It gives precise result	③ It gives approximate result
④ It is also called Conventional Intelligence.	④ It is also called Computational Intelligence.
⑤ It allows sequential computing	⑤ It allow parallel computing.
⑥ Requires lot of computation time	⑥ Requires reasonably less time.
⑦ High cost for solution	⑦ Low cost for solution.
⑧ It requires full truth	⑧ Can work with partial truth.
⑨ Deterministic	⑨ Probabilistic
⑩ Based on binary logic	⑩ Based on fuzzy logic, neural network and probabilistic reasoning.

Biological Neurons and its Structure

Neuron: (i) also called Nerve cell.
(ii) Basic working unit of the brain.
(iii) Specialized cells responsible for sending and receiving signals from the brain.
(iv) They generate electrical signals called action Potentials

Structure of a biological Neuron:

(i) **Dendrite (input):** It receives signals from other neurons.

(ii) **Soma (cell body):** Sums up all the incoming input signals. It also consists of threshold unit.

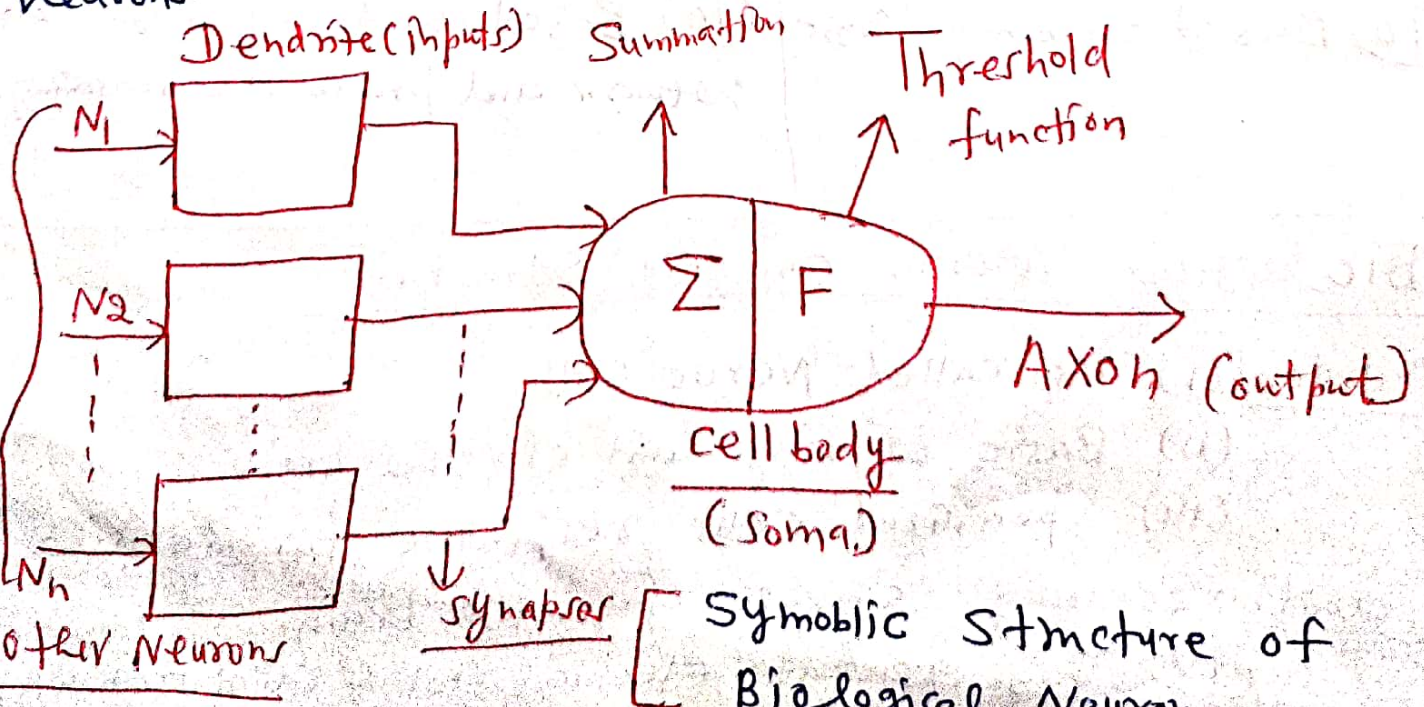
(iii) **Synapse (weighted Connection):** The point of interConnection of one neuron with other neurons. The amount of signal transmitted depends upon the strength (synaptic weights) of the Connection.

Connection can be

(i) Inhibitory (Decreasing) strength

(ii) Excitatory (increasing) strength

(iv) **AXon (output):** when the sum reaches a threshold value, Neuron fires and generates an output signal which travel down to the other neurons.



[Symbolic Structure of Biological Neuron]

Types of biological Neurons

① **Sensory Neurons:** Taste, Smell, hear, see and feel.

② **Motor Neurons:** Voluntary and involuntary movement of muscles and organs.

③ **Interneurons:** Intermediate neurons founds in spinal cord and brain. They pass signals from sensory neurons to motor neurons.

Artificial Neuron and its model

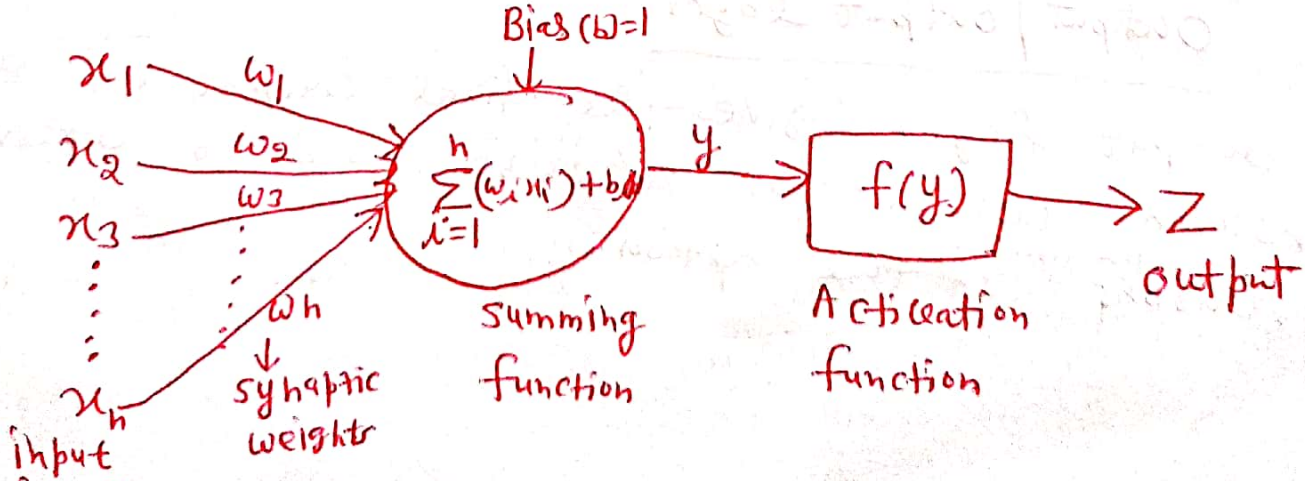
Artificial Neuron: An artificial Neuron is a mathematical function based on the model of biological neurons.

Features of Artificial Neuron:

① Receives inputs from a no. of input signals.

② Weight each input separately and sums them up.

③ Pass this sum through an activation function to produce output.



(Model of Artificial Neuron)

Model of an artificial neuron has 5 Components:

(1) Input values/one input layer:

(i) Input values are passed to a neuron using this layer.

(ii) It is similiar to dendrite in biological neurons.

(2) Synapses/weighted Connection link:

Each Connection link is characterized by a weight or strength (w_i). Each input x_i is multiplied by its weight w_i to get Synaptic strength.

(3) Summing function:

(i) The summing function is used to take the sum of all weighted Connection link.

(ii) A bias value is also added to this weighted sum.

(4) Activation function:

Activation function decides whether or not a neuron is fired based on the output value produced.

(5) output/output layer:

output layer gives the final output of a neuron which can then be passed to other neurons in the networks.

Neural Network / Artificial Neural Network (ANN) (7)

Definition: An artificial neural network (ANN) is the piece of a computing system design to simulate the way human brain analyze & process.

OR

Artificial Neural network is a computational model that consists of several processing elements that receives inputs and deliver outputs based on their predefined activation function. These processing elements are artificial neurons (Nodes).

Features of ANN:

1. **Speed:** faster in processing information. Response time is in nanoseconds.
2. **Processing:** Serial processing is performed in ANN.
3. **Size & Complexity:** It has less size and less complexity. It does not perform complex pattern recognition tasks.
4. **Storage:** Information storage is replaceable means new data can be added by deleting an old one.
5. **Fault tolerance:** It is Fault intolerant i.e. Information once corrupted can not be retrived in case of failure of the system.
6. **Control Mechanism:** There is a Control unit for Controlling Computing activities.

Types of Neural Network (Artificial Neural Network) (8)

In artificial Intelligence:

Parameter	Types	Description
Based on the Connection pattern	Feed-forward, Recurrent	Feed-forward: In this graphs have no loops. Recurrent: Loops occurs due to feedback
Based on the no. of hidden layers	Sihgle Layer Multi-Layer	Sihgle layer: Having one hidden layer (e.g. sihgle perceptron) Multilayer: Having multiple hidden layer (e.g. Multilayer perceptron)
Based on the nature of weights	Fixed Adaptive	Fixed: weights are fixed a priori and not changed at all. Adaptive: weights are updated and changed during training.
Based on Memory units	Static Dynamic	Static: Memory less unit: In this, the current output depends on the current input. e.g. feedforward network Dynamic: memory unit: The output depends upon the current input as well as the current output e.g. Recurrent network.

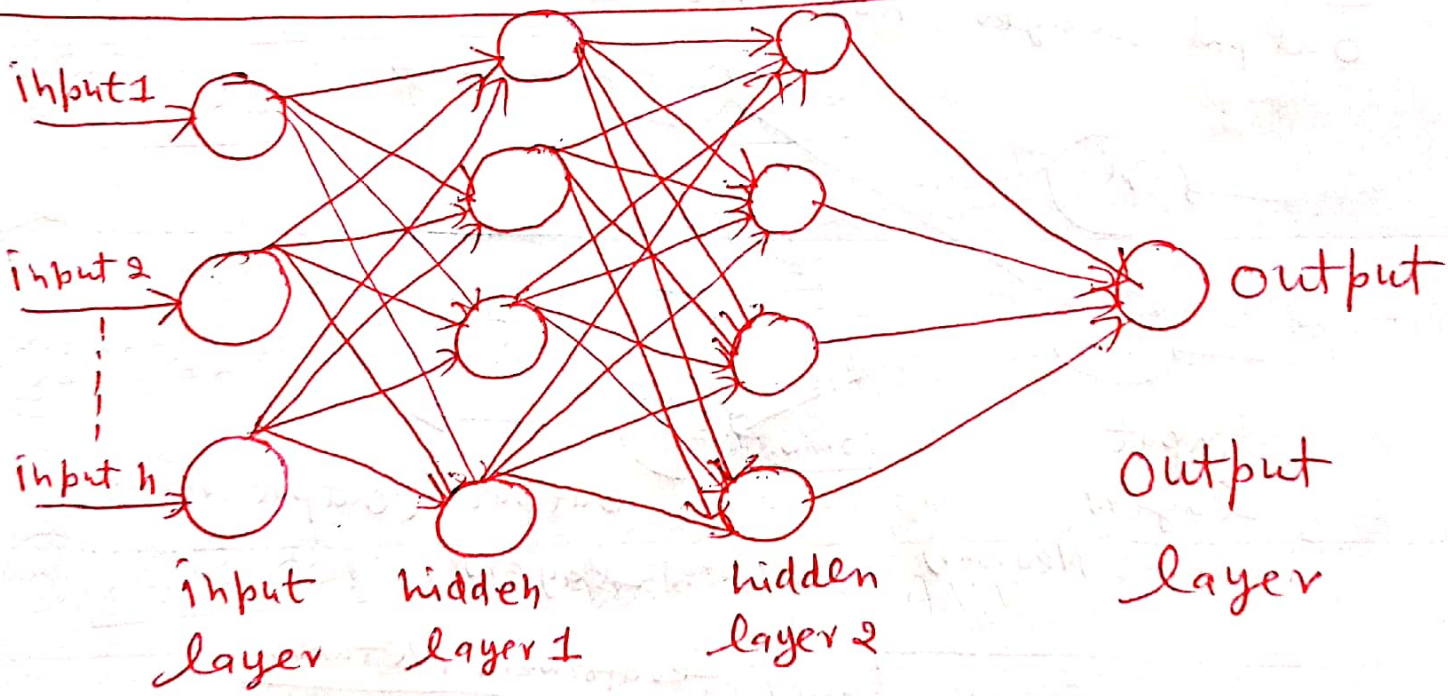
Architecture of ~~Architecture~~ ANN

(1) input layer: It contains those nodes or artificial neurons that receive input from the outside world on which network will learn, recognize them or process otherwise.

(2) Output Layer: It contains node(s) that respond the information about how it is learned any task.

(3) Hidden Layer: Hidden layer(s) are between input and output layers.

Hidden layer Consists of hidden nodes. Hidden nodes or hidden neurons are the neurons that are neither in the input layer nor in the output layer. The word "hidden" implies that they are not visible to the external system and are private to the neural network. There can be zero or more hidden layers in ANN. No. of hidden layers depends on complexity of the problem. There will always be an input layer and output layer.



Architecture of ~~Architect~~ Artificial Neural Network

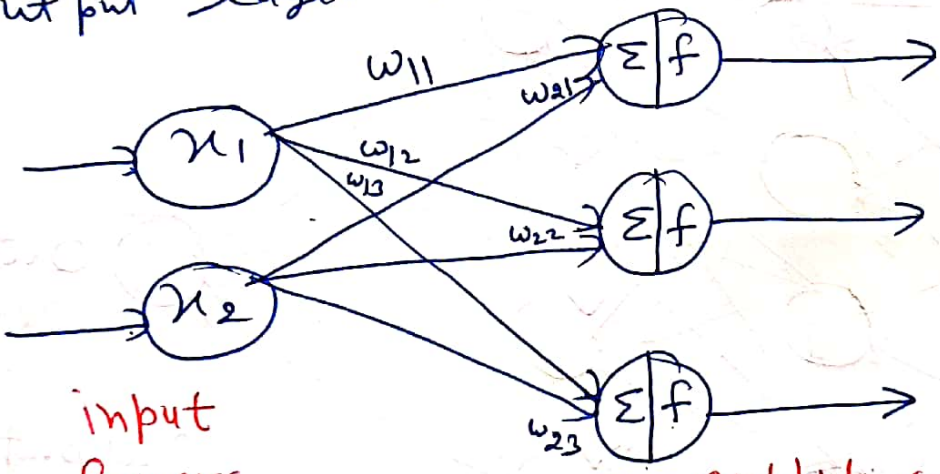
Classification of Artificial Neural Network

There are 3 fundamentally different classes of ANN:

① Single layer feed forward Network

Single layer: There is only one computational layer (output layer), so it is called single layer ANN. However there are two layers (Input layer and output layer).

feedforward network: Input layer forward data to output layer not vice versa.



input layers (input Neurons)

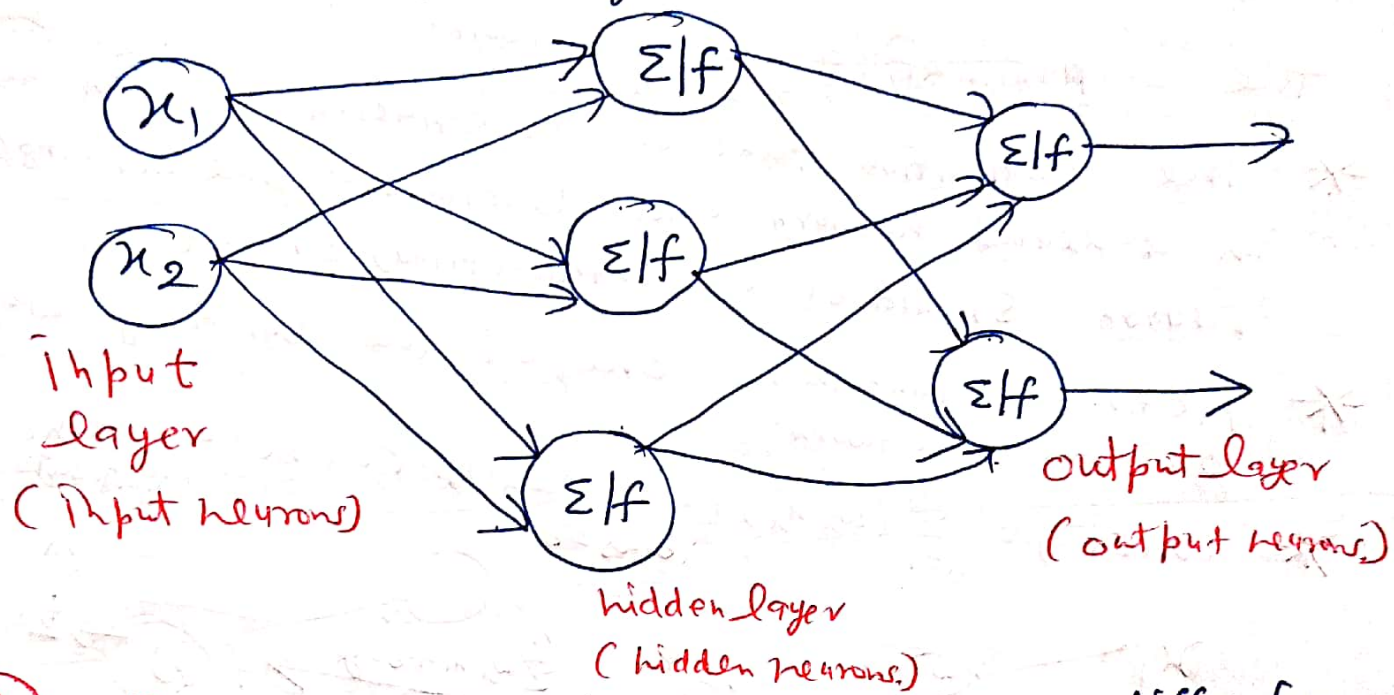
output (output Neurons) layers

Single layer feedforward Network

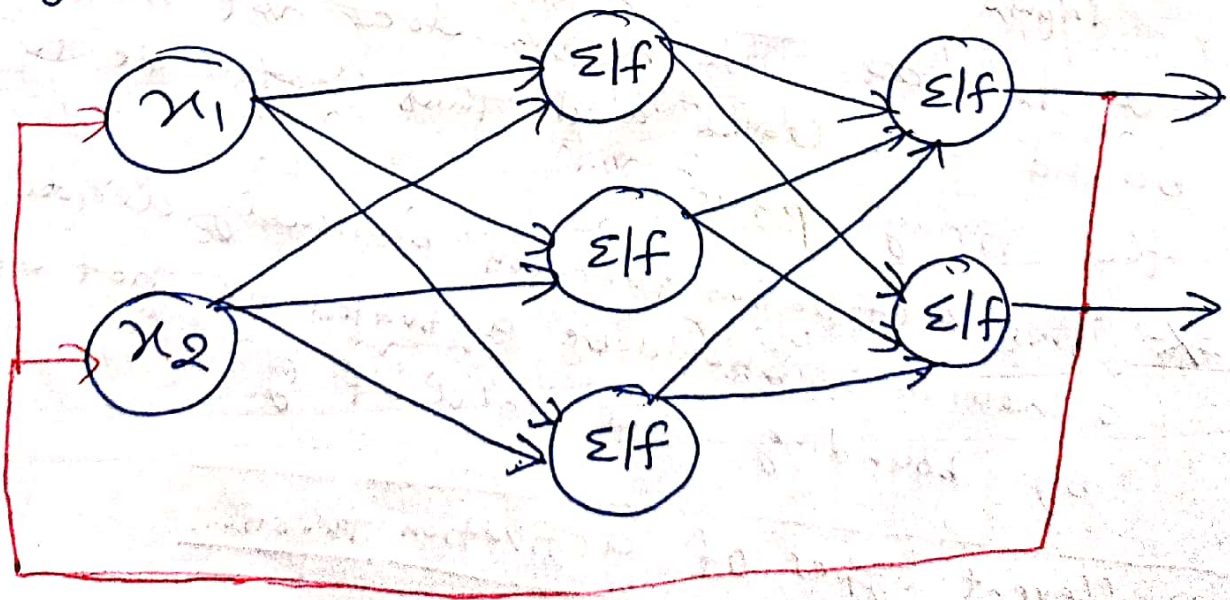
② Multilayer feedforward network:

* In this architecture, there is an input layer, an output layer and one or more intermediate layers called hidden layers.
* The computational units of the hidden layer is called "hidden neurons".

* This hidden layer helps in performing intermediate computation before directing the input to the output layer.



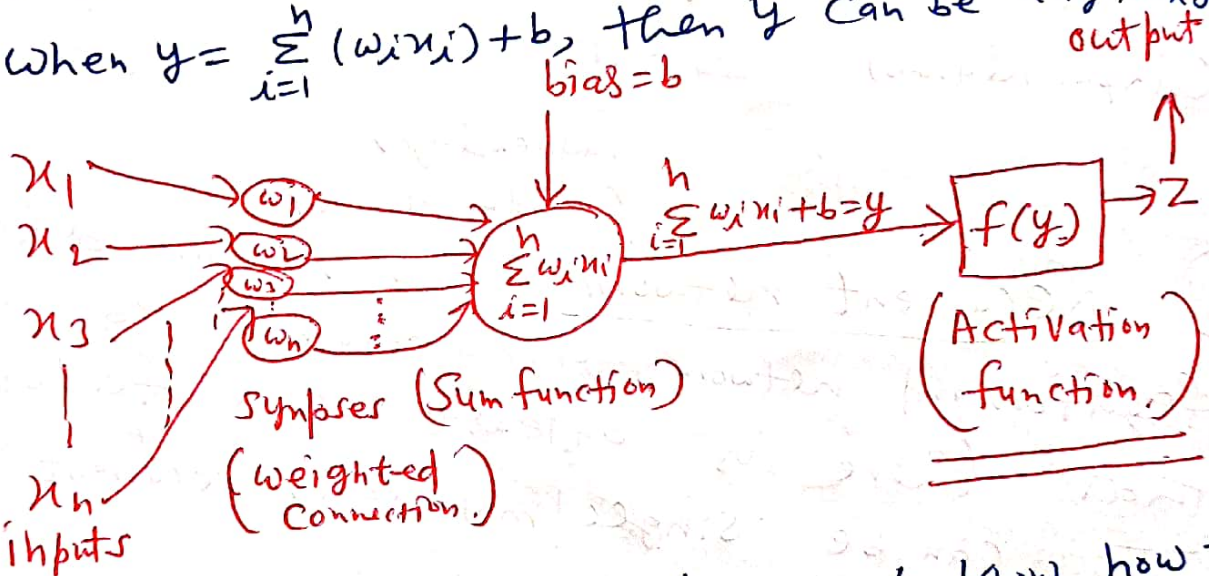
(3) Recurrent network: This network differ from feedforward network architecture in the sense that there is atleast one feedback loop. They can be single/multilayer recurrent network.



Activation functions in Neural Networks (12)

Activation functions: Activation functions are mathematical functions that determines the output of a neural network.

* The activation function is attached to each neuron in a neural network and determines whether the neuron should be "activated" (fired) or not.
* Activation function is one of the building blocks on neural network.
* When $y = \sum_{i=1}^{n} (w_i x_i) + b$, then y can be anything from $-\infty$ to $+\infty$. The neuron does not know how to bound the value and thus not able to decide the firing pattern.



* The activation function basically decide whether a neuron should be activated or not activated by bounding the value of y.

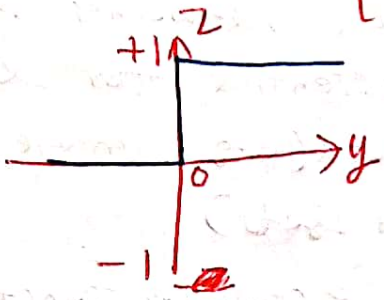
Different types of activation function:

① **Binary Step function**: A binary step function is a threshold based activation function. If the input value is above or

below a certain threshold, the neuron is activated and sends exactly the same signal to the next layer. But it does not allow multi-value output.

$$Z = f(y) = \begin{cases} 0, & y < 0 \\ 1, & y \geq 0 \end{cases} \quad \{0, 1\}$$

↓ Range

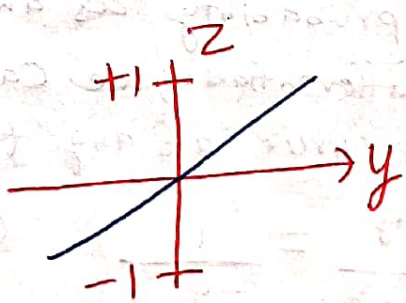


(2) Linear Activation function:

It takes the inputs and create an output signal proportional to the input. It is better than step function in some sense as it allows multiple outputs. However it has limited capability to handle complexity carrying parameters of input data.

$$Z = f(y) = \{y\} \quad \{-\infty, \infty\}$$

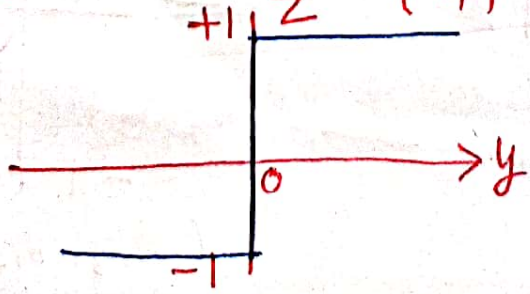
↓ Range



(3) Signum Activation function:

$$Z = f(y) = \begin{cases} -1 & y < 0 \\ 0 & y = 0 \\ +1 & y > 0 \end{cases} \quad \{-1, +1\}$$

↓ range



(4) Non-linear activation function:

* Modern neural network models uses non-linear activation functions
* They allow the model to create complex mapping between the network's inputs and outputs, which are essential for learning and modeling complex data (e.g. image, audio, video, high dimensional data sets)

Adv. of non-linear activation functions

(i) They allow backpropagation because they have a derivative function which is related to the inputs

(ii) They allow "stacking" of multiple layer of neurons to create a deep neural network.

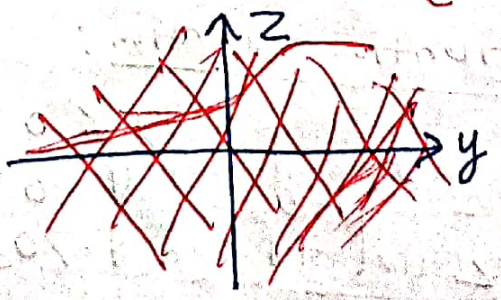
Types of non-linear activation function

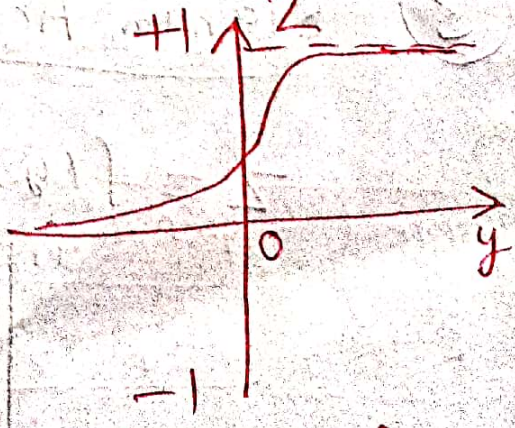
(a) Sigmoid (Logistic) activation function:

(i) It is specially used for models where we have to predict the probability as an output.

(ii) The function is differentiable, we can find the slope of the sigmoid curve at any two points

$$\left\{ z = f(y) = \frac{e^y}{1+e^y} = \frac{1}{e^{-y}+1} \right\} \quad \{0, 1\} \text{ ↓ Range}$$





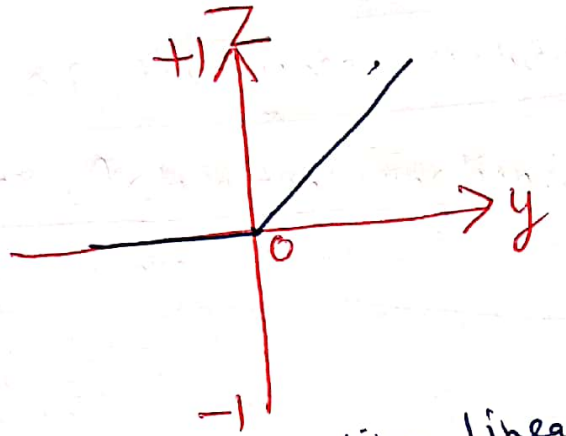
(Sigmoid) function

(b) ReLU (Rectified Linear Unit) function:

* It is most widely used activation function.
* It is used in almost all convolutional neural network or deep learning.

$$Z = f(y) = \begin{cases} 0, & y < 0 \\ y, & y \geq 0 \end{cases} \quad [0, \infty]$$

↓ range



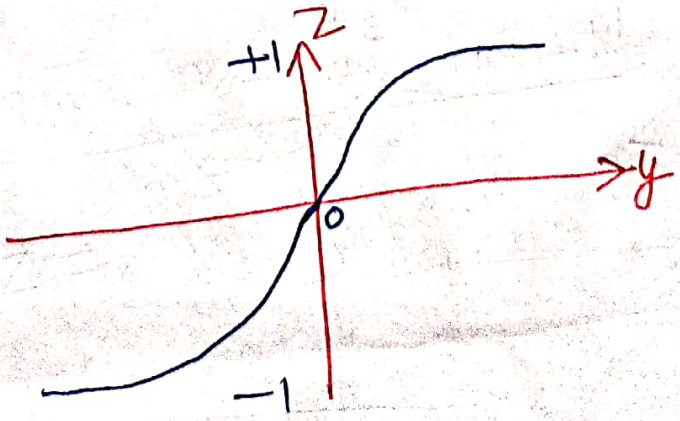
* It looks like linear function but it is a derivative function and used for backpropagation

(C) Hyperbolic tan (tanh):

* tanh is also like logistic sigmoid but better.
* The range of tanh is from (-1 to 1).
* used in feed forward neural networks.

$$Z = f(y) = \frac{e^{y} - e^{-y}}{e^{y} + e^{-y}} \quad [-1, +1]$$

↓ range



Learning Methods in Artificial Neural Networks (ANNs) (16)

* The main property of an ANN is its capability to learn.
* Learning is a process by means of which a neural network adapts itself to a stimulus by making proper parameter adjustments, resulting in the production of desired responses.

* Types of Learning

1. **Parameter learning:** updates the connection weights in a neural network.
2. **Structure Learning:** changes the structure of the network by changing the no. of processing elements as well as their connection types.

These two learning can be applied simultaneously or separately.

Learning Rule: is a procedure (Learning algorithm/training algorithm) for modifying the weights and biases of a network. The purpose of the learning rule is to train the network to perform some tasks.

Types of Learning methods

1. Supervised Learning.
2. Unsupervised Learning
3. Reinforced Learning.

These three types of classification are based on

1. Presence or absence of teacher.
2. The information provided for the system to learn.

Supervised Learning:

* Supervised learning is where you have input variables (x) and an output variable (y) and you use an algorithm to learn the mapping function from the input to the output.

$$Y = f(x)$$

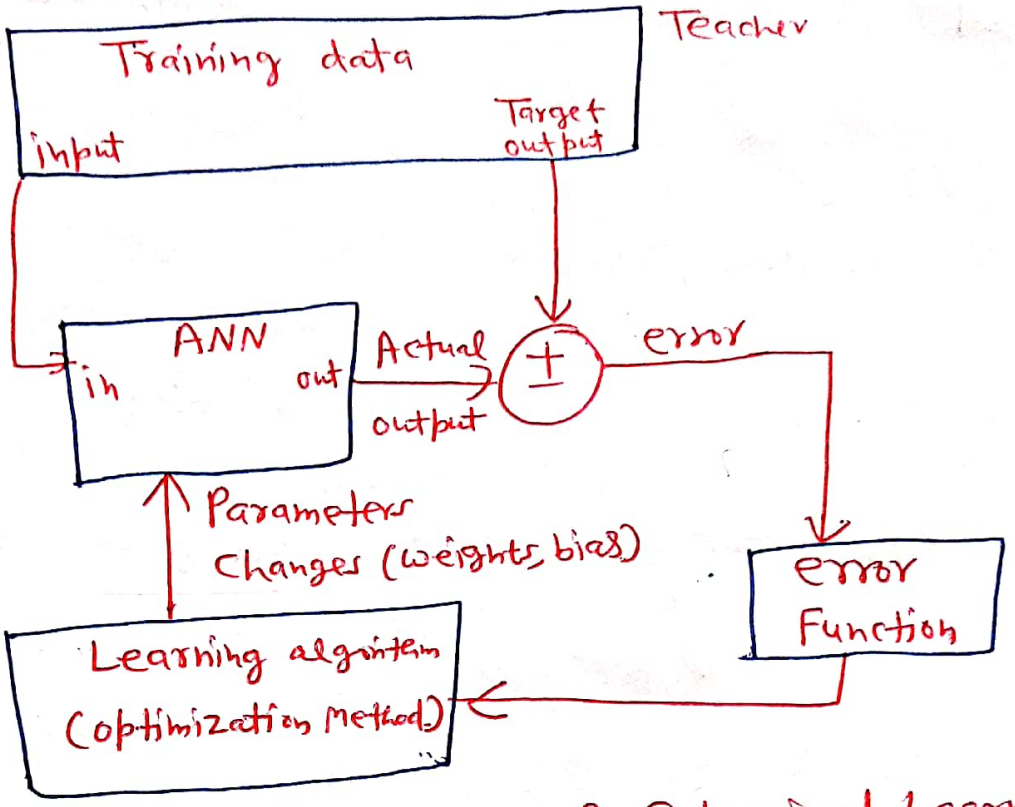
* The goal is to approximate the mapping function so well that when you have new input data (x), then you can predict the output variables (Y) for that data.
* It is called Supervised learning because the process of an algorithm learning from the training dataset can be thought of as a teacher supervising the learning process.
* The algorithm iteratively makes predictions on the training data and is corrected by the teacher.
* Learning stops when the algorithm achieves an acceptable level of performance.

Types of Supervised learning:

(a) Regression (b) Classification.

(a) **Regression:** Regression is the kind of Supervised learning that learns from the labelled dataset and then is able to predict the continuous value output for the new data given to the algorithm.

It is used when the output required is a number such as money (dollar) or weight (kg)



Block diagram of Supervised Learning

Supervised learning Vs Unsupervised learning (19)

Parameters	Supervised Learning	Unsupervised Learning
Definition	A Computer uses given label as example to take and sort series of data and thus to predict the future event. In Supervised learning, people teach or train the machine using labeled data.	Unsupervised learning sorts data without using predefined labels The Unsupervised machine learning algorithms acts without human guidance.
Input data	Uses known and labeled input data	Uses unknown input data
Computational Complexity	More Complex in Computation	Less Complex in Computation
Number of classes	No. of classes is known	No. of classes is not known
Real time	Uses off-line analysis of data	Uses real time analysis of data
Types	Two types of Supervised learning (1) Classification (2) Regression	Two types of Unsupervised learning (1) Clustering (2) Association

Applications of Neural Network
OR
Applications of Artificial Neural Network (ANN)

Ans ① **Handwriting Recognition:** Neural networks are used to convert ~~handwritten~~ hand written characters into digital characters that a machine can recognize.

② **Stock exchange prediction:** The stock exchange is difficult to track and difficult to understand. Many factors affects the stock market. A neural network can examine a lot of factors and predict the price daily, which would ~~help~~ ~~help~~ help stock brokers.

③ **Image Compression:** The idea behind the data compression neural network is to store, encrypt and recreate the actual image again.

④ **Speech Recognition:** Artificial Neural network plays a important role in speech recognition. following ANNs are used for speech recognition.

(i) Multilayer networks (ii) Multilayer networks with recurrent connections
(iii) Kohonen's self-organizing feature map.

⑤ **Human face Recognition:** Following neural networks are used for training purposes with preprocessed image

(a) fully-connected multilayer feedforward neural network trained with the help of backpropagation algorithm.

(b) for dimensionality reduction, Principal Component Analysis (PCA) is used.

(6) Airtraffic Control Could be automated with the location, altitude, direction and speed using ANNs.

(7) Lake Water Levels: ANNs Could be used to predict the lake water levels using precipitation patterns and river/dams flows.

(8) Criminal Sentencing: ANNs Could be used to predict the sentencing of a criminal using a large sample of crime details as input and resulting sentences as output.

Delta Rule:

* The delta rule updates the weights between the connections so as to minimize the difference between the net input to the output unit and the target value.
* The main aim is to minimize the error over all training patterns.
* This is done by reducing the error for each pattern, one at a time.
* The delta rule for adjusting the weight of ith pattern ($i=1$ to n) is

$$\Delta w_i = \alpha (t - y_{in}) x_i$$

for single output

where Δw_i = weight change
α = learning rate
x_i = vector of input unit.
y_{in} = The net input to output unit

$$\Delta w_{ij} = \alpha (t_j - y_{inj}) x_i$$

Delta rule for several output units

① **Learning Rate (α):** The learning rate is denoted by "α". It is used to control the amount of weight adjustment at each step of training. The learning rate, ranging from 0 to 1, determine the rate of learning at each time step.

② **Weight(s):** The weight contains information about the input signal. Each neuron in ANN is connected to other neurons by directed communication links, and each communication link is associated with weights. The weight information is used by the network to solve a problem. The weights can be represented in terms of matrix called Connection matrix

③ **Bias:** The bias included in the network has its impact in calculating the net input. It is included by adding a component $x_0 = 1$ to the input vector X.

Bias can be positive or negative. The positive bias helps in increasing the net input of the network and negative bias helps in decreasing the net input of the network.

④ **Threshold:** Threshold is a set value based upon which the final output of the network may be calculated. The threshold value is used in the activation function. A comparison is made between the calculated net input and the threshold to obtain the network output. For each and every application, there is a threshold limit.

e.g. $f(net) = \begin{cases} +1, & \text{if } net \geq \theta \\ -1, & \text{if } net < \theta \end{cases}$

Difference between biological Neuron and Artificial Neuron

(24)

Parameter	Biological Neuron	Artificial Neuron
Speed	The execution time of biological neuron is of few millisec.	The execution time of artificial neuron is of few nanosec.
Processing	The biological neuron can perform massive parallel operations simultaneously.	The artificial neuron can also perform several parallel operation simultaneously but, in general, the artificial neuron is faster than brain.
Size and Complexity	The size and complexity of a biological neuron is more than that of artificial neuron	The size and complexity of a artificial neuron is less than that of biological neuron
Storage Capacity	The biological neuron stores the information in its interconnections or in synapse strength. The biological neuron sometimes fails to retrieve the stored information.	The artificial neuron stores the information in the contiguous memory location. The artificial neuron always retrieve the stored information.
fault tolerance	The biological neuron possesses fault tolerance capability	The artificial neuron has no fault tolerance.