UNIT-6: ARTIFICIAL NEURAL NETWORK.

6.1. Introduction to Machine Learning

6.2. Types of Machine Learning.

① Supervised learning

② Unsupervised learning

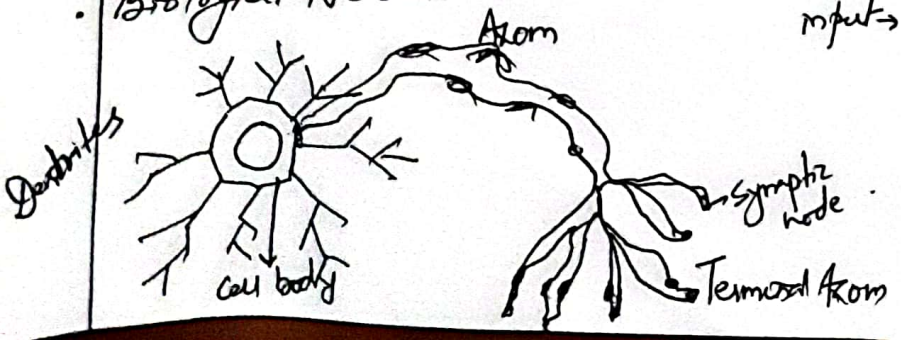
③ Reinforcement learning.

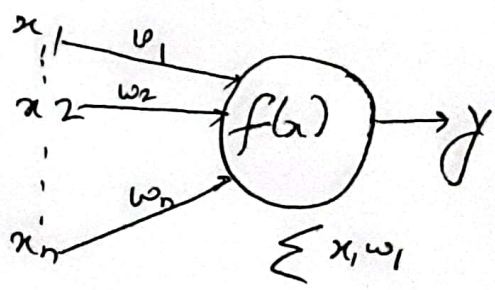
6.3. Introduction to Neural Network.

- Neural Networks are machine learning models that mimic the complex functions of the human brain. These models consist of interconnected nodes or neurons that process data, learn patterns and enable tasks such as pattern recognition & decision making.
- Human brain consists of gazillions of neurons connected to each other, useful for parallel processing. They pass data in very less time.
- Human brain experiences and learn and train data.
- Brain System ⟶ Machines. → learn and train.
  ↓
  Artificial Neural Networks.
- Normal computer doesnot always gives 100% accuracy.
  (Facial expressions may differ, computer may not recognized).
- Input data ⟶ Meaning → learning & Neural Improvement Networks. (Learning algorithm power of NN).
  Algorithms.

6.3.1. Biological Inspiration: neurons and synapse.

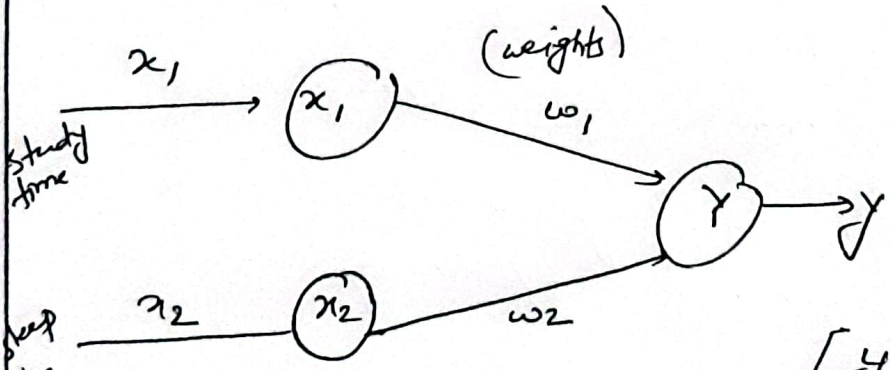
- Biological Neurons:





- Dendrites fetch the input.
- Cell body used for processing
- Axons - through of data are passed.
- Terminal Axon - connected to next dendrites.
- We are implementing biological neuron & the machine with artificial neuron
- <Neurons> : Basic unit (Nodes).
  Data storage area.
- <Layers> : Multiple layers.

- <Connections> : What connection available.
- <Activation function> : Manage the value between (0, 1).
  [best probability output].



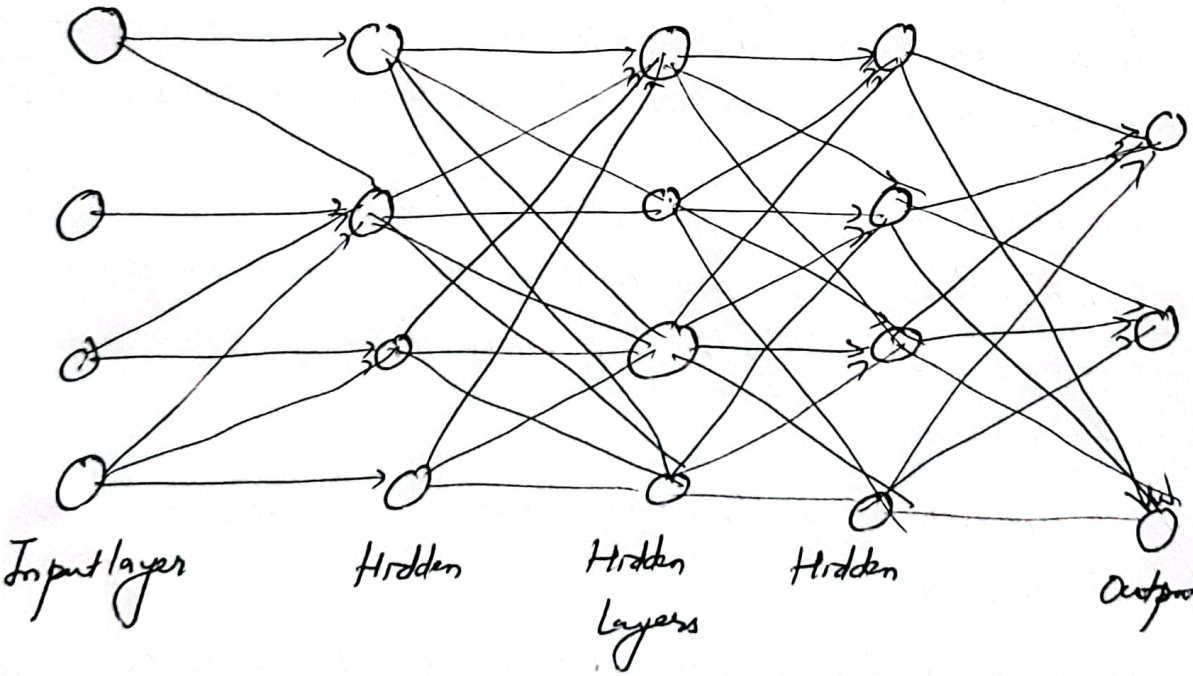
$$[y = x_1 w_1 + x_2 w_2 + b]$$

$$[\sigma(y) = \frac{1}{1+e^{-y}}]$$

$$\begin{bmatrix} w_1 = 0.5 \\ w_2 = -0.3 \\ b_1 = 0.1 \end{bmatrix}$$

2. ⟨Structure of a Neuron⟩

Apart from the living world, in the realm of Computer Science Artificial Neural Networks, a neuron is a collection of a set of inputs, a set of weights and an activation function. It translates these input into a single output, another layer of neurons picks this output and this goes on and on. We can say that each neuron is a mathematical function that closely simulates the functioning of a biological neuron.



6.3.21. ⟨Artificial Neural Network⟩ < Brain>

- It contains artificial neurons which are called units. These units are arranged in a series of layers that together constitute the whole artificial Neural Network in a system.
- It has input layer, hidden layer and output layer.
  - input layer: receives data
  - hidden layer: transform data to valuable part.
  - output layer: provides output.
- Units are interconnected from one layer to another. Each have weights. Through them NN learns more and more & gives best output.

- (Synapse): A specialized junction at which a neuron communicate with a target cell (another neuron / muscle / gland etc).
- At a synapse, a neuron releases chemical transmitter that activates special sites called receptors on the target cell.
- Neuron to neuron → no direct connection → there will be gap → called synapse.
- A synapse is a conceptual analogy to the biological synapse in the human brain. It represents a connection between artificial neurons, which are nodes in neural network.
- Characteristics of a Synapse in AI.

(1) Weight: Each synapse has an associated weight which determines the strength and importance of the connection between neurons.

(2) Signal Transmission: Transfer numeric value from one neuron to another.

(3) Aggregation and Activation: The weighted inputs from multiple synapses are aggregated in a neuron.
(The neuron applies activation function (eg: Sigmoid) to determine the output signal.

	Biological Synapse	AI Synapse.
(1)	Transfers signals between neurons in the brain.	Transfer signals between AN
(2)	Strength depends of neurotransmitters.	Strength depends on the weight.
(3)	Strength changes over time.	Weights updated during training.

6.3.32 <Components of ANN>

① <Weights> : They are parameters associated with the connections between neurons in a neural network.

They determine the strength and influence of a particular input or signal on the output.

- They adjust the contribution of each input to the neuron's output.
- Mathematically; for an input x_i with weight w_i, the contribution is $w_i \cdot x_i$

$$\left[z = \sum_{i=1}^{n} w_i \cdot x_i + b \right]$$

② <Biases> · Additional learnable parameters added to the weighted sum of inputs before applying the activation function. Makes network more flexible.

- Ensure the neuron can fit the data better by shifting the decision boundary.
- Without bias, activation output always pass through the origin.
- Mathematical Representation:

Bias is added to the weighted sum of inputs.

$$\left[z = \sum_{i=1}^{n} w_i \cdot x_i + b \right]$$

③ <Activation Function> : Non linear mathematical function applied to the weighted sum of inputs & bias (+b). Enable to learn complex patterns.

- Solve non linear problems.
- Represent complex function.
- Common Activation functions

1) Sigmoid: $f(z) = \frac{1}{1+e^{-z}}$

Range (0, 1).

2). ReLU (Rectified Linear Unit)

$f(z) = \max(0, z)$

Range: $[0, \infty]$.

3) Tanh: Centers output around zero.

$$f(z) = \frac{e^{z} - e^{-z}}{e^{z} + e^{-z}}$$

Range (-1, 1).

4) Softmax: Used in output layer for multi-class classification.

$$f(z_i) = \frac{e^{z_i}}{\sum_j e^{z_j}}$$

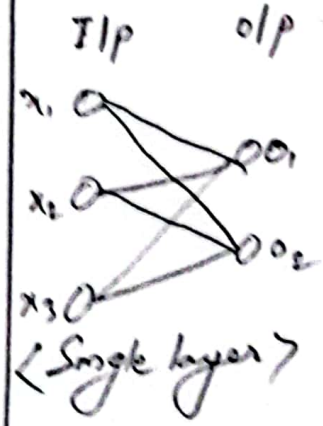
- produces probabilities summing to 1.

Neural Network Architectures.

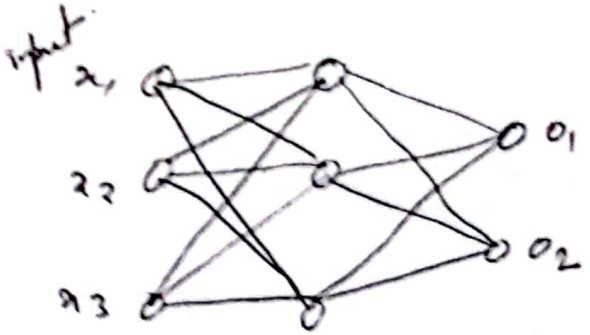
1. Feedforward
2. Convolution
3. Recurrent.

① (Feed forward):

- They are first simplest type of artificial neural network.
- Information moves in only one direction (input to output nodes through hidden nodes)
- There are no cycles or loop in the network
- All inputs with variable weights are connected with every other node.
- A Single layer feed forward → has one layer of nodes
  Multi layer feed forward → has multiple layer of nodes.



(Single layer)



(Multiple layer)

- Data are introduced to system through input layer.
  Input layer of network serves to redistribute input values and does no processing and followed by processing is hidden layers.
- Output data emerge from the final layer.

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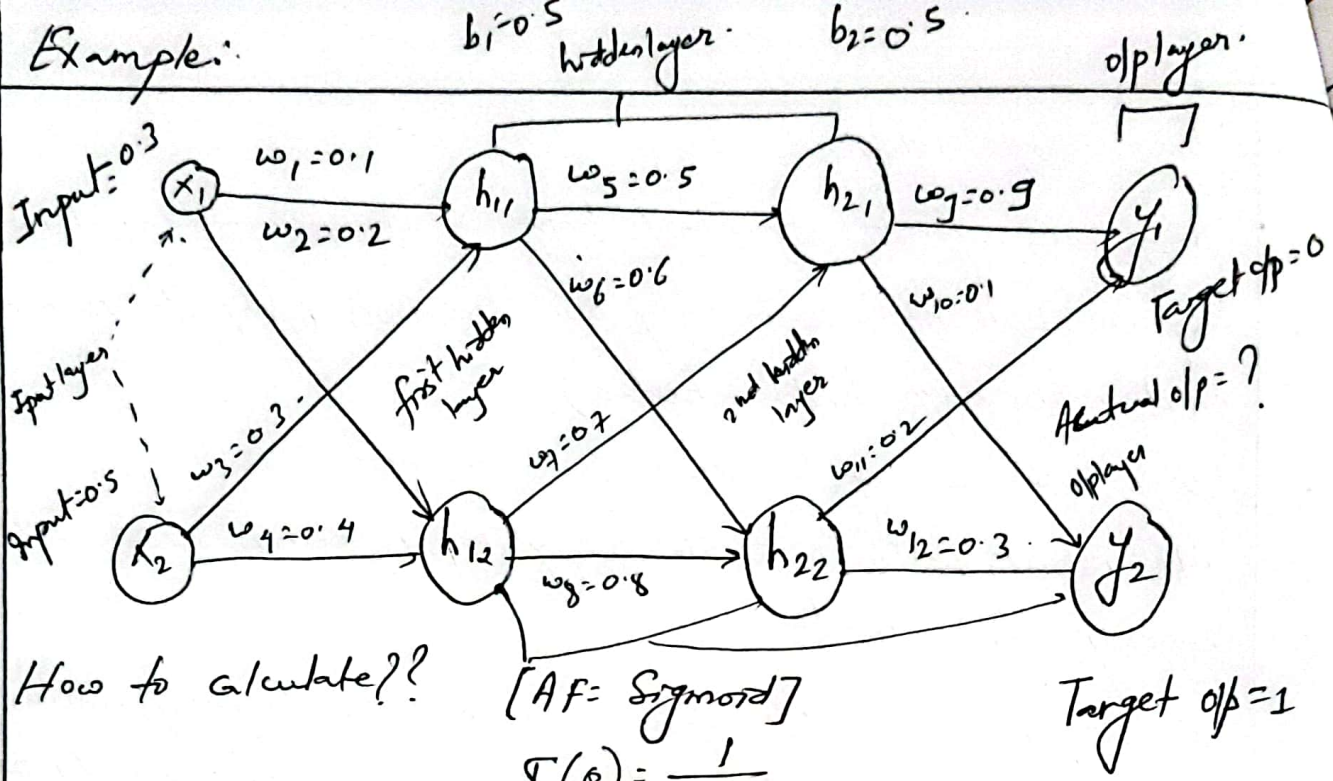
Example:



How to calculate?? [AF= Sigmoid]

Target o/p=1

$$\sigma(\theta) = \frac{1}{1+e^{-\theta}}$$

$$\theta = w_1x_1 + w_2x_2 + w_3x_3 + b_1$$

$$\sigma(\theta) = \frac{1}{1+e^{-(w_1x_1 + w_2x_2 + w_3x_3 + \cdots + b_1)}}$$

- $h_{11} = w_1 \cdot x_1 + w_3 \cdot x_2 + b_1$
  $= 0.1 \times 0.3 + 0.3 \times 0.5 + 0.5$
  $= 0.03 + 0.15 + 0.5$
  $= 0.68$
- $h_{11} = \sigma(h_{11}) = \sigma(0.68) = \frac{1}{1+e^{-0.68}} = 0.66$
- $h_{12} = w_2 \cdot x_1 + w_4 \cdot x_2 + b_1$
  $= 0.2 \times 0.3 + 0.4 \times 0.5 + 0.5$
  $= 0.06 + 0.2 + 0.5$
  $= 0.76$

$\sigma(h_{12}) = \sigma(0.76) = \frac{1}{1+e^{-0.76}} = 0.68$

- Input for h_{21} will be output of h_{11} & h_{12}.
  [0.68 & 0.766]

- $h_{21} = w_5 \cdot \sigma(h_{11}) + w_7 \sigma(h_{12}) + b_1$
  $= 0.5 \times 0.66 + 0.7 \times 0.68 + 0.5$
  $= 0.33 + 0.476 + 0.5$
  $= 1.306$
  $\therefore \sigma(h_{21}) = 0.786$

- $h_{22} = w_6 \sigma(h_{11}) + w_8 \cdot \sigma(h_{12}) + b_1$
  $= 0.6 \times 0.66 + 0.8 \times 0.76 + 0.5$
  $= 1.504$
  $\therefore \sigma(h_{22}) = 0.818$

- For output layer:
  $\rightarrow y_1 = w_9 \cdot \sigma(h_{21}) + w_{11} \sigma(h_{22}) +$
  $= 0.3 \times 0.786 + 0.2 \times 0.818$
  $= 0.1636$
  $\therefore \sigma(y_1) = 0.54$

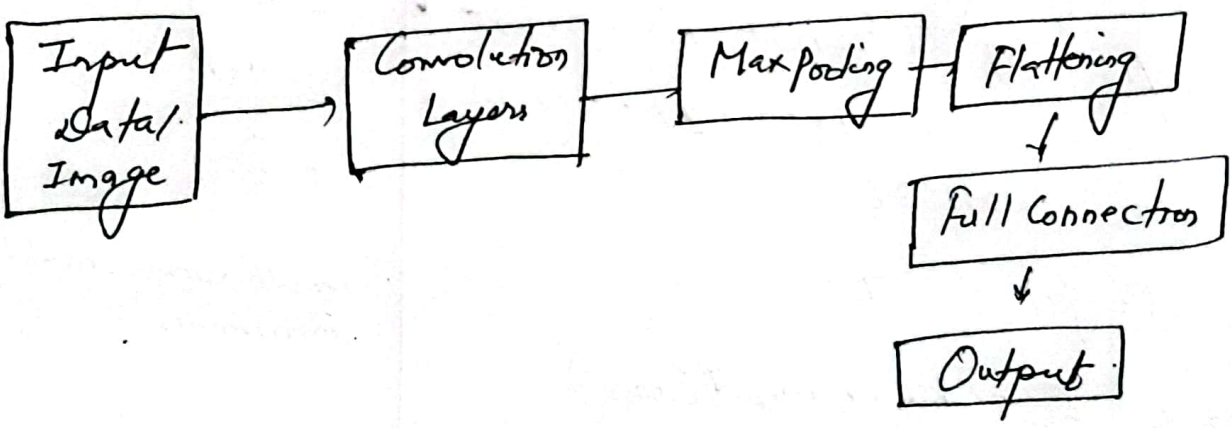
- $\rightarrow y_2 = w_{10} \sigma(h_{21}) + w_{12} \sigma(h_{22})$
  $= 0.1 \times 0.786 + 0.3 \times 0.818$
  $= 0.324$
  $\therefore \sigma(y_2) = 0.58$

- EL: Mean Squared Error
  $= \frac{1}{2}\left[(y_A' - y_T')^2 + (y_A^2 - y_T^2)^2\right]$
  $= \frac{1}{2}\left[(0.54-0)^2 + (0.58-1)^2\right]$
  $= \frac{1}{2}(0.2916 + 0.1764)$
  $= \frac{0.468}{2}$
  $= 0.234$

$\therefore$ overall error should be minimum.

6.3.32. ⟨Convolution Neural Network⟩ CNN.

- They are widely used in image recognition, images classifications, objects detections, recognition faces etc.
- CNN image classifications take an input image, process it and classify it under certain categories.
- CNN is another type of neural network that can be used to enable machines to visualize things & perform tasks such as image classification, image recognition & object detection etc...
- Image classification is the task of taking an input image and outputting a class or a probability of classes that best describes the images.
- Specialized type of neural network model designed for working with image data.



∴ Structure of CNN

Q. Differentiate between FFNN & CNN?
Q. Explain types of machine learning.
Q. Explain different labels of structure of CNN.