Name - Srishti Pravin Kavadi
PRN - 22610005

ANN Assignment 1

Q1) What is an artificial neuron?

→ i) An artificial neuron is a mathematical function that mimics the behaviour of biological neuron in a neuron network. Artificial neural networks consist of artificial neurons called units arranged in layers: input, hidden and output. The input layer receives external data, which is processed by hidden layer to extract meaningful patterns. The output layer generates the final result.

ii) Each unit is connected to other through weighted connections, influencing how data flow through the network. During training, these weights are adjusted to optimize performance. Inspired by human neurons ANN's learn from data, improving their ability to recognize pattern and make predicate.

Q2) Explain McCulloch-Pitts Neuron Model.

→ The McCulloch-Pitts (M-P) is a simple yet powerful model that mimic the basic working of a biological neuron using mathematical framework.

i] Structure of the Mc neuron:

- Input (x_i) - Binary value (0 or 1) representing the presence or absence of a signal
- weights (w_i) - Assigned to each i/p where $w_i = +1$ for excitatory input
  $w_i = -1$ for inhibitory input.

PRN: 22610005

- Summation function (S) – compute the weighted sum of inputs $S = \sum_{i=1}^{n} w_i x_i^k$
- Threshold (τ) – A predefined value that determine whether the neuron activates.
- Activation function – A step function that gives an o/p based on summation result.

ii] Mathematical Model:

The firing rule of the (M-P) neuron is defined as,

$$o^{k+1} = \begin{cases} 1, & \text{if } \sum_{i=1}^{n} w_i x_i^k \geq \tau \\ 0, & \text{if } \sum_{i=1}^{n} w_i x_i^k < \tau \end{cases}$$

- if the weighted sum of i/p meet or exceed the threshold (τ), the neuron is fired. otherwise, it remains inactive.

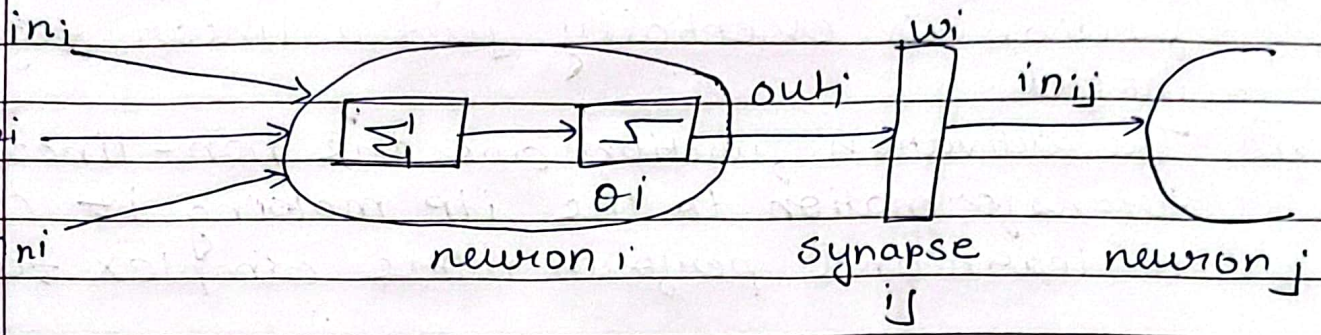
iii] Advantages:

1. Simple & Binary
2. Implements logic function
3. Sequential Processing (Memory cell)
4. Foundation for neural network.

iv] Limitations:

1. No learning mechanism (model can't adapt)
2. Does not handle continuous value of input

PRN: 22610005



$$in_{ki} = out_k \, w_{ki}$$

$$out_j = sgn\left(\sum_{k=1}^{n_i} in_{ki} - \theta_i\right)$$

$$in_{ij} = out_i \, w_{ij}$$

Q3) What is an activation function and why it is needed?

→ i) The activation function decide whether a neuron should be activated or not by calculating the weight sum and further adding bias to it. The purpose of the activation function is to introduce non-linearity into output of a neuron.

ii) We know, the neural network has neuron that work in correspondance with weight, bias and their respective activation function.

iii) In a neural network, we should update the weight and bais of neuron on the basis of the error at the output. This process is known as back propagation.

iv) Activation function makes the back propagation possible since the gradients are supplied along with the error to update the weight and bias.

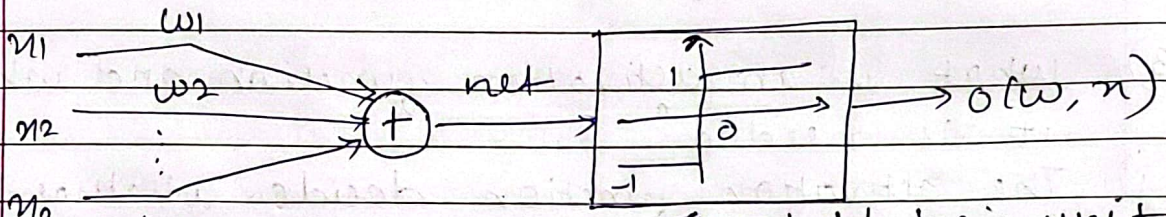
PRN - 2261005

v) A neural network without an activation function is essentially just a linear regression model.

vi) The activation function does the non-linear transformation to the i/p making it capable to learn and perform more complex task.

Q4) What is a binary perceptron and continuous perceptron.

→ 1) Binary Perceptron (Threshold logic unit):-



Threshold logic unit.

Structure & functionality:

- Input $(x_1, x_2, \ldots x_n)$: Represented as binary value (0 or 1)
- weight $(w_1, w_2, \ldots w_n)$: Assigned to each i/p
- Summation Node (net)

$$net = \sum_{i=1}^{n} w_i x_i$$

- Threshold logic unit (step function)

$$o(w_2 x) = \begin{cases} 1, & \text{if } net \geq T \\ 0, & \text{if } net < T \end{cases}$$

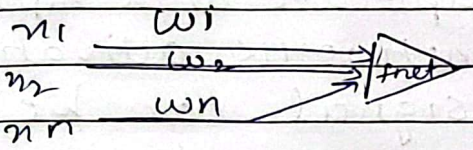
- If net i/p exceed fixed Threshold(T) Fire neuron (1)
- otherwise remain inactive (0).

PRN- 22610005

Page No.: 11 | Date: | YOUVA

Application :
- Implement basic gates (AND, OR, NOR etc.)
- Used in McCulloch - Pits neuron for symbolic processing.

2) Continuous Perceptron :



$$f(net) = \frac{2}{1+e^{-\lambda net}} - 1$$

Structure & Functionality :
- input and wt: same as binary perceptron
- Activation function - sigmoid function.

$$f(net) = \frac{2}{1+e^{-\lambda net}} - 1$$

- The function smoothly maps net i/p value between -1 and 1.
- λ control steepness of the function.

Advantage over Binary Perceptron :
1) Continuous o/p : suitable for classification problem where probabilities are needed.
2) Differentiability : Allow gradient based learning back propogation.
3) Better Generalization : works well for complex problem like image recognition and deep learning.

PRN - 22610005

Page No.: Date: YOUVA

Application:
- Used in multi-layer perceptron
- Applied in machine learning, AI and pattern recognition.

Q5) Explain continuous and discrete activation functions as well as unipolar and bipolar.

→ In artificial neural network activation function and neural signal can be categorized into continuous and discrete as well as unipolar and bipolar types.

a) Continuous activation function:
- The o/p is a neuron is a continuous value within a given range (e.g - 0 to 1 or -1 to 1)
- example: sigmoid, tanh, relu.
- Used in deep learning and gradient based optimization since it allows smooth changes and backpropagation.

b) Discrete activation function:
- The output of neuron is limited to distinct value. eg (0 or 1, -1 or 1)
- example - Threshold function (step function)
- Mostly used in perceptron and binary classification tasks.

c) Unipolar representation:
- The output value are non-negative usually in the range [0, 1]
- It is commonly used when modelling binary classification with o/p like ON(1) and OFF(0)

PRN - 22610005

- example :
  - Unipolar step function:

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

  - Unipolar sigmoid function

$$f(n) = \frac{1}{1+e^{-n}}$$

d) Bipolar representation :
- The output value range between [-1, 1] allowing both +ve & -ve.
- useful for representing two opposite states (+1 yes or -1 no)
- example :
  - Bipolar step function

$$f(n) = \begin{cases} 1, & n \geq 0 \\ -1, & n < 0 \end{cases}$$

  - Bipolar sigmoid function

$$f(n) = \frac{1-e^{-n}}{1+e^{-n}}$$