ASSIGNMENT - 1 : IMRAZ ZIYA
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Mc Culloch - Pitts (MCP) Neuron Model :

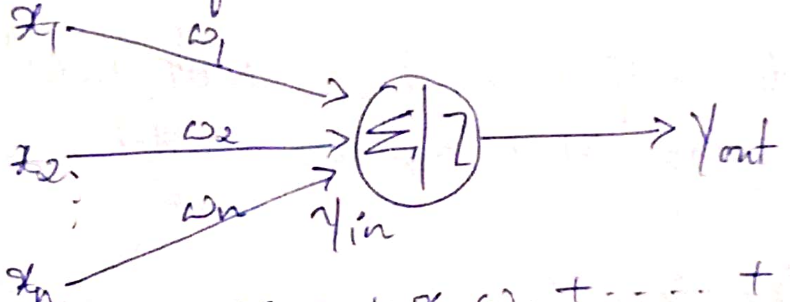
(I) Give the Architecture of the MCP neural network model

Ans: The MCP Neural Network Model refers to the McCulloch-Pitts Neural Network, which is one of the earliest models of artificial neurons.

The most fundamental unit of deep neural network is a perceptron.

The very first step towards the perception we use today was taken in 1943 by Warren McCulloch and Walter Pitts.

Architecture of the MCP neural Network:-



$$Y_{in} = x_1\omega_1 + x_2\omega_2 + \dots + x_n\omega_n$$
$$= \sum_{i=1}^{n} x_i\omega_i$$

(i) Input Layer:
- A set of Binary inputs $x_1, x_2, x_3, \dots x_n$
- Each input represents a feature or variable and takes a Binary value 0 or 1

(ii) Weights:
- Each input x_i is associated with a weight w_i, which represents the importance of the input.
- The weighted sum of inputs is calculated as

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

(iii) Summation Function

Computes the linear combination (weighted sum) of inputs:

(iv) Threshold Function:-

- A threshold θ is applied to the weighted sum Y_{in}
- if ~~$\theta \ge T$~~ $y_{in} \ge \theta$ the neuron fires (output=1)
- if $y_{in} < T$, the neuron does not fire (output=0)

Mathematically

$$Y_{out} = f(y_{in}) = \begin{cases} 1 & \text{if } y_{in} \ge \theta \\ 0 & \text{if } y_{in} < \theta \end{cases}$$

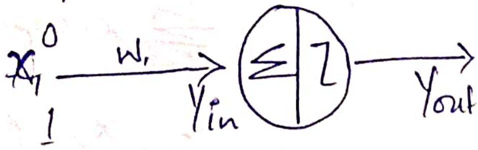
(v) Output :-

- A single binary output Y_{out}, which represents the activation state of the neuron.

(2) Generate the output of logic NOT, NAND, and NOR functions using MCP neuron model.

Ans:- NOT:-

One input:



Net input $Y_{in} = X_1 w_1 = X_1$

Truth Table

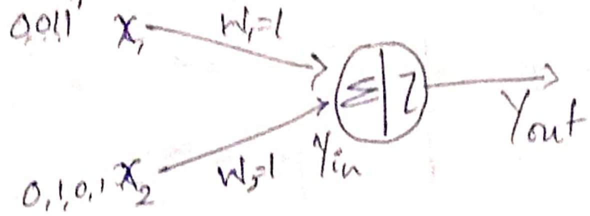
X (input)	Output (Y_{out} = NOT(X))	$Y_{in} = X_1$
0	1	0
1	0	1

Activation function:

$$Y_{out} = f(y_{in}) = \begin{cases} 1 & \text{if } y_{in} \geq 1 \\ 0 & \text{if } y_{in} < 1 \end{cases}$$

NAND:

2 inputs



$$Y_{in} = x_1 w_1 + x_2 w_2 = \text{NAND}(x_1, x_2)$$

Truth Table

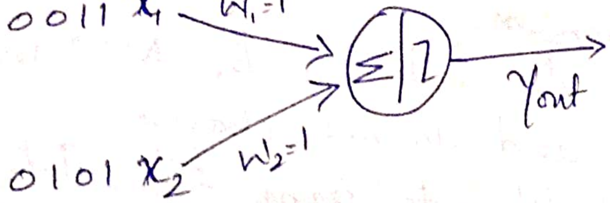
x_1	x_2	NAND (x_1, x_2)	$Y_{in} = x_1 + x_2$
0	0	1	0
0	1	1	1
1	0	1	1
1	1	0	2

Activation function

$$y_{out} = f(y_{in}) = \begin{cases} 1 & \text{if } y_{in} \geq 2 \\ 0 & \text{if } y_{in} < 2 \end{cases}$$

NOR

2 inputs



$$Y_{in} = x_1 w_1 + x_2 w_2 = x_1 + x_2$$

Truth Table

x_1	x_2	NOR (x_1, x_2)	$Y_{in} = x_1 + x_2$
0	0	1	0
0	1	0	1
1	0	0	1
1	1	0	2

Activation Function

$$y_{out} = f(y_{in})$$

$$= \begin{cases} 1 & \text{if } y_{in} \geq 2 \\ 0 & \text{if } y_{in} < 2 \end{cases}$$

(3) Write the limitations of MCP neuron model

Ans:- The MCP neuron model is a foundational concept in artificial neural networks, but it has several limitations that make it unsuitable for complex tasks.

Here are the key limitations:

(i) Binary Inputs and Outputs

- The MCP model only works with binary inputs (0 & 1) and produces binary outputs.
- It cannot handle continuous & multi-valued inputs and outputs, which are essential for real-world problems.

(ii) Linear Separable Problems Only:

- The MCP model can only solve problems that are linearly separable (AND, OR).
- It fails to solve problems like XOR, which require non-linear separability.

(iii) No Learning Mechanism:-

- The weights and thresholds in the MCP model are manually assigned and do not change
- It lacks the ability to learn from data through training process, which is critical feature of modern neural networks.

(iv) No support for Non-Binary Logic:

- The model cannot represent & process fuzzy logic & probabilistic outputs, which are important for handling uncertainity and ambiguity.

(v) Static Architecture:

- The MCP model has fixed structure with no provision for adding hidden layers or neurons
- Modern neural networks leverage multi-layer architectures to capture complex patterns, which the MCP model cannot achieve

(vi) No activation Function Flexibility :-

- The MCP neuron uses a simple step function for activation, limiting its ability to model complex relationships between inputs and outputs
- It cannot use modern activation functions like sigmoid, ReLU or softmax, which enable richer functionality

(vii) Lack of Feedback or Recurrent Connections:

- The MCP model is a feedforward network, which means information flows in one direction only.
- It cannot model temporal or sequential data, which requires recurrent or feedback connections.

(viii) Limited Practical Applicability :-

- Due to its simplicity, the MCP model cannot address modern machine learning tasks like image recognition, natural language processing, or speech synthesis.