INDIVIDUAL TASK (MODULE 1)

1.Build a Perceptron model to solve a binary classification problem and apply the Perceptron Learning Law.

ABSTRACT

This report presents the construction and training of a Perceptron model for solving a binary classification problem using the Perceptron Learning Law. The Perceptron, introduced by Frank Rosenblatt in 1958, is one of the earliest models in Artificial Neural Networks. In this assignment, the AND gate dataset is used as a simple example of a linearly separable binary classification problem. The structure of the Perceptron, mathematical formulation, learning rule, training process, and final results are explained in detail. The model is trained step by step by updating weights and bias iteratively until correct classification is achieved. The advantages and limitations of the Perceptron are also discussed. This experiment demonstrates the fundamental working principle of supervised learning in neural networks.

INTRODUCTION

Introduction

Artificial Neural Networks (ANN) are computational models inspired by the working mechanism of biological neurons in the human brain. These networks consist of interconnected artificial neurons that process information and learn patterns from data. Neural networks are widely used in machine learning, pattern recognition, classification, prediction, and various artificial intelligence applications. They are especially powerful in solving complex real-world problems where traditional rule-based programming methods may not provide accurate results.

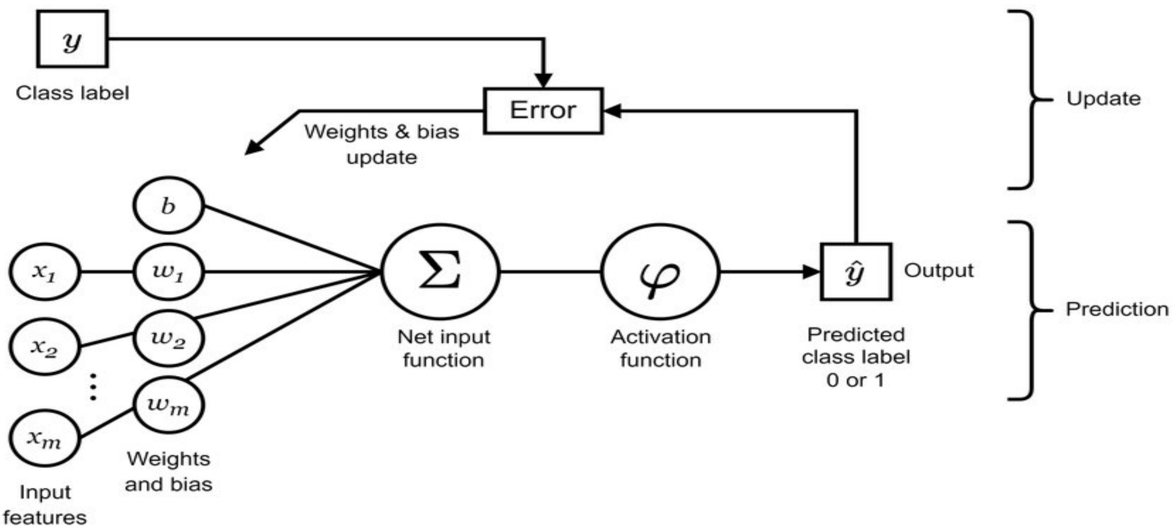
One of the earliest and simplest neural network models is the Perceptron. The Perceptron is a supervised learning algorithm used for solving binary classification problems. It works by calculating a weighted sum of input values and applying an activation function to determine the output. In simple terms, it finds a linear decision boundary that separates data into two distinct classes. Due to its simplicity, the Perceptron became the foundation for the development of more advanced neural network models.

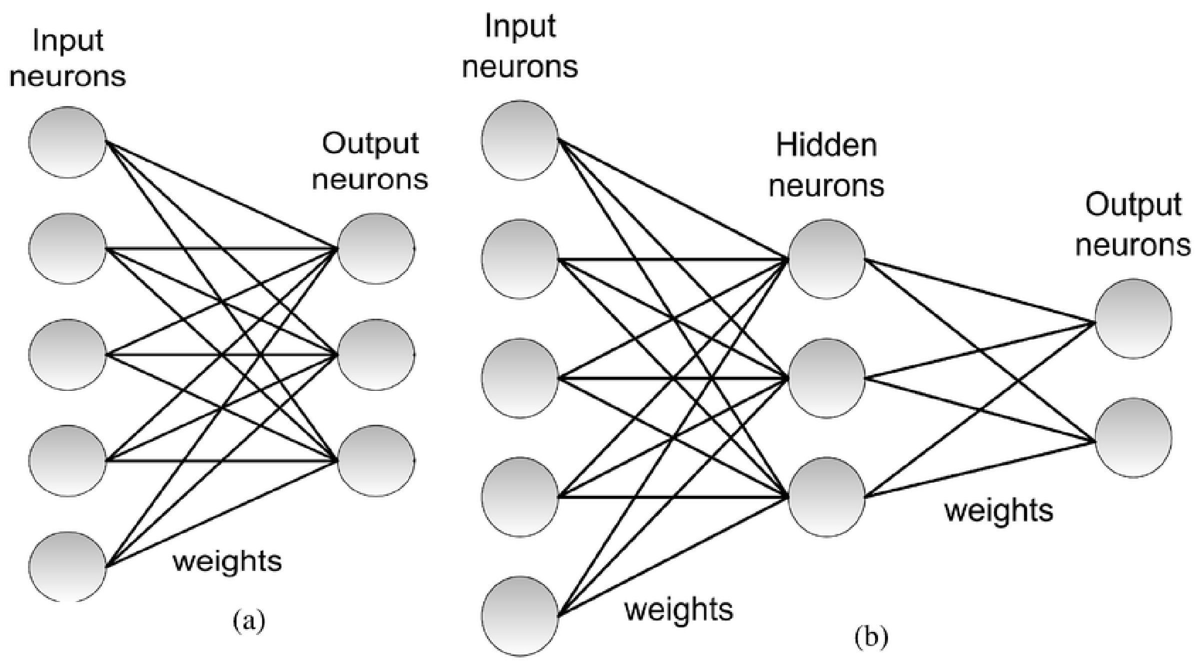
Although the single-layer Perceptron can only solve linearly separable problems, it played a crucial role in the evolution of neural network research. It laid the foundation for more advanced architectures such as Multilayer Perceptron (MLP) and Deep Neural Networks (DNN). These advanced models use multiple hidden layers and sophisticated learning techniques to overcome the limitations of the basic Perceptron. As a result, they are capable of handling complex real-world applications such as image recognition, speech processing, medical diagnosis, financial forecasting, and many other intelligent systems.

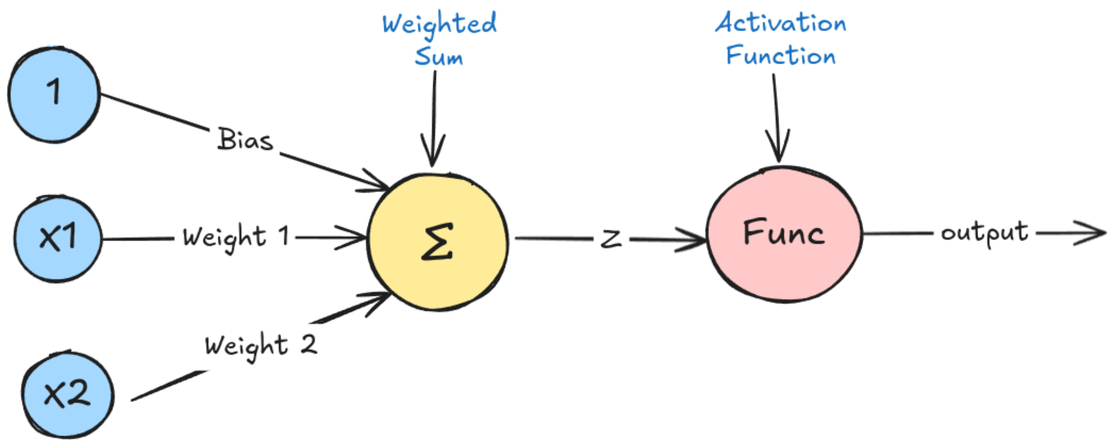
Therefore, Artificial Neural Networks and the Perceptron model are fundamental concepts in machine learning and artificial intelligence. They form the backbone of modern deep learning technologies and continue to contribute significantly to the advancement of intelligent computing systems.

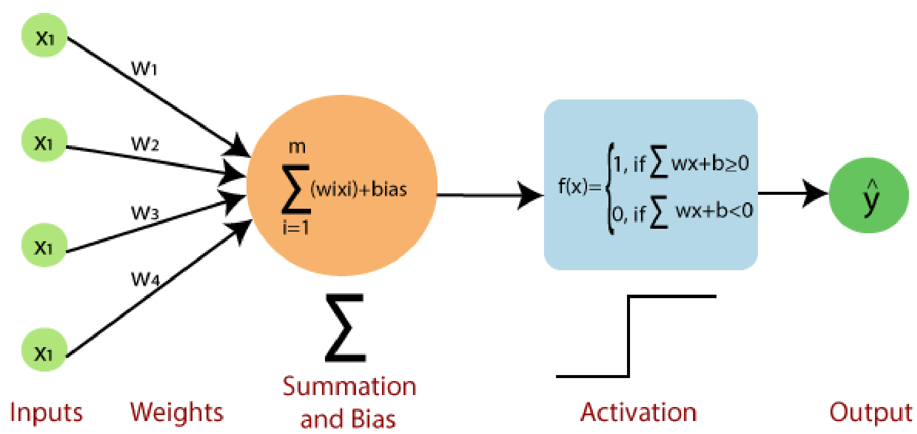
<u>THEORETICAL BACKGROUND</u>

Perceptron Model









The Perceptron is a single-layer feedforward neural network. It consists of:

- Input layer ($x_1, x_2, \ldots, x_n$)
- Weights ($w_1, w_2, \ldots, w_n$)
- Bias (b)
- Summation unit
- Activation function (Step function)
- Output (y)

Each input is multiplied by its corresponding weight. The weighted inputs are summed along with a bias term. The result is passed through an activation function to produce the final output.

MATHEMATICAL REPRESENTATION

The net input to the neuron is calculated as:

$$Z = w_1x_1 + w_2x_2 + \ldots + w_nx_n + b$$

The activation function is defined as:

$$y = \begin{cases} 1, & \text{if } Z \geq 0 \\ 0, & \text{if } Z < 0 \end{cases}$$

This function helps in classifying the output into one of two classes.

PROBLEM STATEMENT

To demonstrate the Perceptron model, we consider a binary classification problem using the AND gate dataset.

Training Dataset:

x_1 x_2 Target (T)

0 0 0

0 1 0

1 0 0

1 1 1

The objective is to train the Perceptron so that it correctly classifies all the input patterns according to the AND logic.

METHODOLOGY

Initialization

Initially, we assume:

$w_1 = 0$
$w_2 = 0$
$b = 0$
Learning rate (η) = 1

PERCEPTRON LEARNING LAW

The Perceptron Learning Rule updates weights whenever there is a classification error.

Weight update formula:

$$w_i(new) = w_i(old) + \eta(T - O)x_i$$

Bias update formula:

$$b(new) = b(old) + \eta(T - O)$$

Where:

T = Target output

O = Observed output

η = Learning rate

The training process continues for several epochs until the output matches the target for all input combinations.

IMPLEMENTATION (TRAINING PROCESS)

Epoch 1

For input (0,0):

Z = 0 → Output = 1 → Error = -1

Bias updated to -1

For input (0,1):

Correct classification → No change

For input (1,0):

Correct classification → No change

For input (1,1):

Error = 1

Weights updated:

$w_1 = 1$

$w_2 = 1$

b = 0

Further Training

After multiple epochs, the weights converge to:

$w_1 = 1$

$w_2 = 1$

$b = -2$

RESULTS

The final decision function is:

$$Z = x_1 + x_2 - 2$$

Testing all inputs:

x_1	x_2	Z	Output
0	0	-2	0
0	1	-1	0
1	0	-1	0
1	1	0	1

The Perceptron correctly classifies all input combinations. Therefore, the model successfully solves the binary classification problem.

ADVANTAGES

The Perceptron has several advantages in Artificial Neural Networks. It is simple, easy to understand, and computationally efficient. The training process involves basic arithmetic operations, making it fast and suitable for small datasets. It converges quickly when the dataset is linearly separable. Additionally, it forms the foundation for more complex neural network architectures such as multilayer perceptrons and deep neural networks. Because of its simplicity, it is widely used for teaching fundamental concepts of supervised learning.

LIMITATIONS

The main limitation of the Perceptron is that it can only classify linearly separable data. It fails to solve non-linear problems such as XOR classification. The hard threshold activation function limits its flexibility compared to modern neural networks that use differentiable activation functions. It is restricted to binary classification and cannot directly handle multi-class problems without modification. These limitations led to the development of advanced neural network models.

APPLICATIONS

The Perceptron is used in simple pattern recognition tasks, basic classification problems, and as a building block in multilayer neural networks. It is also used in educational settings to explain the fundamentals of supervised learning and neural network training.

CONCLUSION

In this assignment, a Perceptron model was built to solve a binary classification problem using the AND gate dataset. By applying the Perceptron Learning Law step by step, the weights and bias were updated iteratively until the model achieved correct classification. The experiment demonstrates how supervised learning works in Artificial Neural Networks. Although the Perceptron has certain limitations, it remains an essential foundational concept in ANN.

In this assignment, a Perceptron model was developed to solve a binary classification problem using the AND gate dataset. By applying the Perceptron Learning Law iteratively, the weights and bias were updated until the model correctly classified all input combinations. This experiment demonstrates the basic principle of supervised learning and linear classification in Artificial Neural Networks. Although the Perceptron is limited to linearly separable problems, it remains a fundamental and important model that forms the foundation for advanced neural network architectures.