# Chapter 8: Neural Network

## Introduction

Neural networks are the backbone of modern Artificial Intelligence. Inspired by the human brain, they are designed to mimic the way humans learn and make decisions. In Class 11 AI, we explore the **basic concepts of neural networks**, **their architecture**, and how they are used in **machine learning applications**. This chapter introduces students to the fundamental ideas of artificial neurons and how networks of such neurons are created for intelligent computing.

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## 8.1 Biological vs Artificial Neural Network

### 8.1.1 Biological Neural Network (BNN)

- The human brain consists of billions of neurons.
- A **neuron** receives input signals through **dendrites**, processes them in the **cell body**, and sends output through the **axon**.
- These biological neurons communicate via **synapses**, allowing the brain to process complex information, learn, and adapt.

### 8.1.2 Artificial Neural Network (ANN)

- ANN is a mathematical model inspired by BNN.
- It consists of **nodes (neurons)** connected with **weights**, simulating the working of synapses.
- Each neuron in an ANN takes input, applies a mathematical operation (often non-linear), and produces an output.

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## 8.2 Structure of an Artificial Neural Network

An ANN typically consists of three types of layers:

### 8.2.1 Input Layer

- Accepts raw data/features for processing.
- Each neuron in this layer corresponds to one input feature.

### 8.2.2 Hidden Layer(s)

- One or more layers between input and output layers.
- Perform intermediate computations and extract patterns from data.
- The more hidden layers, the **deeper** the network (used in Deep Learning).

### 8.2.3 Output Layer

- Produces the final result (e.g., classification or regression output).
- Number of neurons depends on the problem (e.g., 2 for binary classification, multiple for multiclass classification).

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## 8.3 Components of a Neuron (Perceptron)

A single neuron (also called **perceptron**) works like this:

### Inputs

- Denoted as `x1, x2, x3, ..., xn`.

### Weights

- Each input is multiplied with a weight: `w1, w2, ..., wn`.

### Summation Function

- The sum of weighted inputs is calculated: `z = w1*x1 + w2*x2 + ... + wn*xn + b` (Here, `b` is the **bias**.)

### Activation Function

- Applies a non-linear function to the result, such as:
    - **Sigmoid**
    - **ReLU (Rectified Linear Unit)**
    - **Tanh**

This helps the model learn complex patterns.

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## 8.4 Types of Neural Networks

### 8.4.1 Feedforward Neural Network

- Information flows in one direction — from input to output.
- No cycles or loops.
- Used in basic classification and regression tasks.

### 8.4.2 Convolutional Neural Network (CNN)

- Mainly used in **image processing** and **computer vision**.
- Applies filters (convolutions) to extract features like edges, shapes, and textures.

### 8.4.3 Recurrent Neural Network (RNN)

- Used for **sequential data** like time series, speech, or text.
- Maintains a memory of previous inputs.

## 8.5 Applications of Neural Networks

- **Image Recognition**: Face detection, object classification.
- **Natural Language Processing (NLP)**: Chatbots, translators, sentiment analysis.
- **Healthcare**: Disease detection, diagnostic systems.
- **Finance**: Fraud detection, stock predictions.
- **Self-driving Cars**: Recognizing signs, lanes, and pedestrians.

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## 8.6 Learning Process in Neural Networks

### 8.6.1 Forward Propagation

- Inputs are passed through the network to get predictions.
- Each layer processes data and passes it to the next.

### 8.6.2 Loss Function

- Calculates the difference between predicted and actual output.
- Common loss functions: Mean Squared Error (MSE), Cross Entropy.

### 8.6.3 Backpropagation

- Adjusts weights using **Gradient Descent** to reduce the error.
- Repeats many times (epochs) to improve accuracy.

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## 8.7 Limitations of Neural Networks

- **Data Hungry**: Needs a large amount of labeled data.
- **Computational Cost**: Requires powerful hardware (GPUs).
- **Black Box Nature**: Difficult to interpret how decisions are made.
- **Overfitting**: Performs well on training data but poorly on new data if not regulated.

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## 8.8 Key Terms

| Term | Description |
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| Neuron | Basic unit of computation in a neural network |
| Weight | A value that determines the importance of an input |
| Bias | Additional parameter to help model make better predictions |
| Activation Func. | A function that adds non-linearity to the network |
| Epoch | One complete cycle through the entire training dataset |
| Loss Function | Measures how far the prediction is from the actual value |

| Term | Description |
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| Backpropagation | A method of updating weights to minimize loss |

## Summary

Neural networks are powerful tools in Artificial Intelligence that mimic the human brain. By using layers of interconnected neurons, they can learn patterns from data and make intelligent predictions. In this chapter, we explored the structure of artificial neural networks, their working, types, and practical applications. While neural networks are at the core of many modern AI systems, they also come with limitations like high data requirements and low interpretability. However, with careful design and training, they offer remarkable capabilities in fields ranging from image recognition to language processing.