Chapter 10: Introduction to Neural Networks

Introduction

Artificial Intelligence (AI) aims to enable machines to mimic human intelligence. One of the most revolutionary techniques that allow machines to "think" like humans is **Neural Networks**. Inspired by the human brain, neural networks form the backbone of **deep learning**—a subfield of AI that excels in tasks like image recognition, natural language processing, and even self-driving cars.

In this chapter, you will explore what neural networks are, how they work, and where they are used in real life.

10.1 What is a Neural Network?

A **Neural Network** is a computational model designed to simulate how the human brain analyzes and processes information. It is composed of layers of nodes, also called **neurons**, that are connected to each other and work collectively to learn from data.

Key Concepts:

- **Neuron**: The basic unit in a neural network that receives inputs, processes them, and produces an output.
- **Weights**: The strength of the connection between neurons.
- **Bias**: A constant added to the input to adjust the output.
- **Activation Function**: A function that decides whether a neuron should be activated or not.

10.2 Structure of a Neural Network

A neural network consists of three main types of layers:

1. Input Layer

- The first layer where the data enters the system.
- Each neuron in this layer represents a feature (e.g., pixels in an image).

2. Hidden Layers

- One or more layers where actual computation happens.
- Each neuron in these layers is connected to all neurons in the previous and next layers.

3. Output Layer

- The final layer that provides the prediction or classification result.

[Diagram Placeholder: Basic Neural Network Architecture]

```
Input Layer --> Hidden Layer(s) --> Output Layer
```

10.3 Working of a Neural Network

Let's understand how a neural network works step-by-step:

Step 1: Input

- The input layer receives data, e.g., numbers representing an image or a sentence.

Step 2: Weighted Sum

- Each input is multiplied by a weight, and the weighted sum is calculated.

Step 3: Add Bias

- A bias is added to the weighted sum to fine-tune the output.

Step 4: Apply Activation Function

- The result goes through an activation function like:
    - **Sigmoid**: Output between 0 and 1.
    - **ReLU** (Rectified Linear Unit): Outputs 0 if negative, otherwise the input.
    - **Tanh**: Output between -1 and 1.

Step 5: Output

- The final result is passed to the next layer or shown as output.

10.4 Types of Neural Networks

Type	Description	Use Case
Feedforward Neural Network (FNN)	Information moves in one direction	Image classification
Convolutional Neural Network (CNN)	Specialized for image data	Face recognition, object detection
Recurrent Neural Network (RNN)	Has memory; suitable for sequences	Speech, language translation

---

10.5 Applications of Neural Networks

1. **Image Recognition** – Identify objects, faces, handwriting.
1. **Speech Recognition** – Used in assistants like Alexa, Siri.
2. **Healthcare** – Disease prediction using medical images.
3. **Finance** – Credit scoring, stock price prediction.
4. **Autonomous Vehicles** – Lane detection, obstacle recognition.

10.6 Limitations of Neural Networks

- **Data Hungry**: Requires large datasets.
- **Black Box**: Difficult to interpret how the model arrived at a result.
- **Computationally Expensive**: Needs high processing power and memory.

Key Terms

Term	Definition
Neuron	Basic processing unit of a neural network.
Weight	Importance given to input data.
Bias	An additional parameter to fine-tune the output.
Activation Function	Helps in deciding the output of the neuron.
Feedforward	Data moves in one direction – from input to output.
Backpropagation	A method for updating weights to reduce error.

Summary

In this chapter, you explored the basics of **Neural Networks**, an essential concept in modern Artificial Intelligence. Neural networks mimic the human brain's structure and can learn from large amounts of data. They consist of interconnected layers of neurons and rely on functions like activation and backpropagation to make accurate predictions. Neural networks have vast applications, from facial recognition and language translation to autonomous vehicles and healthcare diagnostics. While powerful, they do have limitations, primarily their need for large datasets and computational resources.

Understanding neural networks lays the groundwork for more advanced topics like **Deep Learning** and **AI model training**, which are critical for real-world AI applications.
