ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING

DAY – 12

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NEURAL NETWORKS

Neural networks are machine learning models that mimic the complex functions of the human brain. These models consist of interconnected nodes or neurons that process data, learn patterns and enable tasks such as pattern recognition and decision-making.

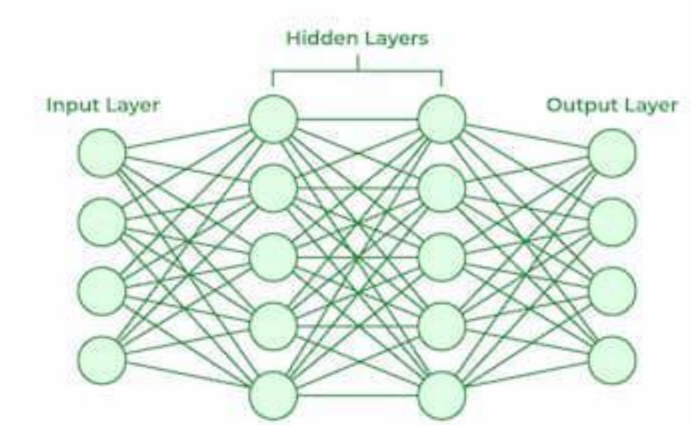
Understanding Neural Networks in Deep Learning

Neural networks are capable of learning and identifying patterns directly from data without pre-defined rules. These networks are built from several key components:

1. **Neurons:** The basic units that receive inputs, each neuron is governed by a threshold and an activation function.
2. **Connections:** Links between neurons that carry information, regulated by weights and biases.
3. **Weights and Biases:** These parameters determine the strength and influence of connections.
4. **Propagation Functions:** Mechanisms that help process and transfer data across layers of neurons.
5. **Learning Rule:** The method that adjusts weights and biases over time to improve accuracy.

Layers in Neural Network Architecture

- **Input Layer:** This is where the network receives its input data. Each input neuron in the layer corresponds to a feature in the input data.
- **Hidden Layers:** These layers perform most of the computational heavy lifting. A neural network can have one or multiple hidden layers. Each layer consists of units (neurons) that transform the inputs into something that the output layer can use.
- **Output Layer:** The final layer produces the output of the model. The format of these outputs varies depending on the specific task like classification, regression.



Working of Neural Networks

1. Forward Propagation

When data is input into the network, it passes through the network in the forward direction, from the input layer through the hidden layers to the output layer. This process is known as forward propagation. Here's what happens during this phase:

- **Linear Transformation:** Each neuron in a layer receives inputs which are multiplied by the weights associated with the connections. These products are summed together and a bias is added to the sum. This can be represented mathematically as:
  $z=w_1x_1+w_2x_2+\ldots+w_nx_n+b$
  Where w represents the weights, x represents the inputs, b is the bias
- **Activation:** The result of the linear transformation (denoted as zz) is then passed through an activation function. The activation function is crucial because it introduces non-linearity into the system, enabling the network to learn more complex patterns. Popular activation functions include ReLU, sigmoid and tanh.

2. Backpropagation

After forward propagation, the network evaluates its performance using a loss function which measures the difference between the actual output and the predicted output. The goal of training is to minimize this loss. This is where backpropagation comes into play:

- **Loss Calculation:** The network calculates the loss which provides a measure of error in the predictions. The loss function could vary; common choices are mean squared error for regression tasks or cross-entropy loss for classification.
- **Gradient Calculation:** The network computes the gradients of the loss function with respect to each weight and bias in the network. This involves applying the chain rule of calculus to find out how much each part of the output error can be attributed to each weight and bias.
- **Weight Update:** Once the gradients are calculated, the weights and biases are updated using an optimization algorithm like stochastic gradient descent (SGD). The weights are

adjusted in the opposite direction of the gradient to minimize the loss. The size of the step taken in each update is determined by the learning rate.

3. Iteration

This process of forward propagation, loss calculation, backpropagation and weight update is repeated for many iterations over the dataset. Over time, this iterative process reduces the loss and the network's predictions become more accurate.

Through these steps, neural networks can adapt their parameters to better approximate the relationships in the data, thereby improving their performance on tasks such as classification, regression or any other predictive modeling.

Types of Neural Networks

There are seven types of neural networks that can be used.

- **Feedforward Networks:** A feedforward neural network is a simple artificial neural network architecture in which data moves from input to output in a single direction.
- **Singlelayer Perceptron:** A single-layer perceptron consists of only one layer of neurons . It takes inputs, applies weights, sums them up and uses an activation function to produce an output.
- **Multilayer Perceptron (MLP):** MLP is a type of feedforward neural network with three or more layers, including an input layer, one or more hidden layers and an output layer. It uses nonlinear activation functions.
- **Convolutional Neural Network (CNN):** A Convolutional Neural Network (CNN) is a specialized artificial neural network designed for image processing. It employs convolutional layers to automatically learn hierarchical features from input images, enabling effective image recognition and classification.
- **Recurrent Neural Network (RNN):** An artificial neural network type intended for sequential data processing is called a Recurrent Neural Network (RNN). It is appropriate for applications where contextual dependencies are critical such as time series prediction and natural language processing, since it makes use of feedback loops which enable information to survive within the network.
- **Long Short-Term Memory (LSTM):** LSTM is a type of RNN that is designed to overcome the vanishing gradient problem in training RNNs. It uses memory cells and gates to selectively read, write and erase information.