Deep Neural Networks

An Engineer's Handbook

The Sarasvati Project

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1. Everything About Perceptron

1.1 What is a perceptron?

A perceptron is a fundamental building block in the world of deep learning! It's a simple yet powerful model that acts as a single artificial neuron within a neural network. Here's how it works: Imagine a perceptron as a gatekeeper. It takes in a bunch of information (represented by numbers) as its input, like the features of an image or the words in a sentence. Inside, it performs a calculation on this information using weights and a bias. Think of the weights as adjustable knobs that control how much each piece of information affects the decision. The bias is like a threshold that the combined weighted information needs to cross to pass through the gate. The key output of a perceptron is a binary classification: either 0 or 1. Based on its calculation, the perceptron decides whether the input belongs to one class or the other. For example, in image classification, it might decide if an image contains a cat or not. Here are some key points about perceptrons:

- **They are linear classifiers:** This means they can only draw straight lines to separate data points into different classes. This limits their ability to handle complex data patterns.
- **They are the foundation of neural networks:** Multi-layer perceptrons, which are networks of interconnected perceptrons, can handle more complex data by combining the decisions of multiple layers.
- **They are simple and easy to understand:** This makes them a great starting point for learning about deep learning and how neural networks work.

1.2 Types of Perceptrons

1. **Single-Layer Perceptron:** This type of perceptron is limited to learning linearly separable patterns. effective for tasks where the data can be divided into distinct categories through a straight line.
2. **Multilayer Perceptron:** Multilayer perceptrons possess enhanced processing capabilities as they consist of two or more layers, adept at handling more complex patterns and relationships within the data.

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1.4 Basic Components of Perceptron

A perceptron, the basic unit of a neural network, comprises essential components that collaborate in information processing.

1. **Input Features:** The perceptron takes multiple input features, each input feature represents a characteristic or attribute of the input data.
2. **Weights:** Each input feature is associated with a weight, determining the significance of each input feature in influencing the perceptron's output. During training, these weights are adjusted to learn the optimal values.
3. **Summation Function:** The perceptron calculates the weighted sum of its inputs using the summation function. The summation function combines the inputs with their respective weights to produce a weighted sum.
4. **Activation Function:** The weighted sum is then passed through an activation function. Perceptron uses Heaviside step function functions. which take the summed values as input and compare with the threshold and provide the output as 0 or 1.
5. **Output:** The final output of the perceptron, is determined by the activation function's result. For example, in binary classification problems, the output might represent a predicted class (0 or 1).
6. **Bias:** A bias term is often included in the perceptron model. The bias allows the model to make adjustments that are independent of the input. It is an additional parameter that is learned during training.
7. **Learning Algorithm (Weight Update Rule):** During training, the perceptron learns by adjusting its weights and bias based on a learning algorithm. A common approach is the perceptron learning algorithm, which updates weights based on the difference between the predicted output and the true output.

These components work together to enable a perceptron to learn and make predictions. While a single perceptron can perform binary classification, more complex tasks require the use of multiple perceptrons organized into layers, forming a neural network.

1.5 How does Perceptron work?

A weight is assigned to each input node of a perceptron, indicating the significance of that input to the output. The perceptron's output is a weighted sum of the inputs that have been run through an activation function to decide whether or not the perceptron will fire. it computes the weighted sum of its inputs as:

$$z = w_1x_1 + w_2x_2 + \cdots + w_nx_n = x^T w$$

The step function compares this weighted sum to the threshold, which outputs 1 if the input is larger than a threshold value and 0 otherwise, is the activation function that perceptrons utilize the most frequently. The most common step function used in perceptron is the Heaviside step function:

$$h(z) = \begin{cases} 0 & \text{if } z < Threshold \\ 1 & \text{if } z \geq Threshold \end{cases}$$

A perceptron has a single layer of threshold logic units with each TLU connected to all inputs.