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Neural Network and Applications

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Abstract: *A neural network is a method in artificial intelligence (AI) that teaches computers to process data in a way that is inspired by the human brain. It is a type of machine learning (ML) process, called deep learning, that uses interconnected nodes or neurons in a layered structure that resembles the human brain. A neural network is a machine learning program, or model, that makes decisions in a manner similar to the human brain, by using processes that mimic the way biological neurons work together to identify phenomena, weigh options and arrive at conclusions. In simple terms, a neural network is a set of algorithms designed to recognize patterns or relationships in a given dataset.*

Keywords: Terminals, Monitoring, PC, Internet, Application, Notification

I. INTRODUCTION

What is Perceptron?

While it's true that AI growth in 2023 was expansive, the first neural network was created in 1958 by research psychologist Frank Rosenblatt called the perceptron.

A perceptron is a simple model of a biological neuron used in an artificial neural network. The four parts of a perceptron are input features, weights, a bias term, and an activation function. Inputs are weighted and summed, adjusted by bias, and passed through the activation function to produce the output. By combining multiple perceptrons in layers and connecting them in a network structure, these models can learn and represent complex patterns and relationships in data, enabling tasks such as image recognition, natural language processing, and decision making. Moreover, a perceptron can be considered as a neural network with a single layer.

Perceptron Algorithm

The perceptron algorithm works by taking a set of input values and producing an output based on the dot product of the input values and the corresponding weights. The output is then passed through an activation function (usually a step function) to produce a binary output, either 0 or 1.

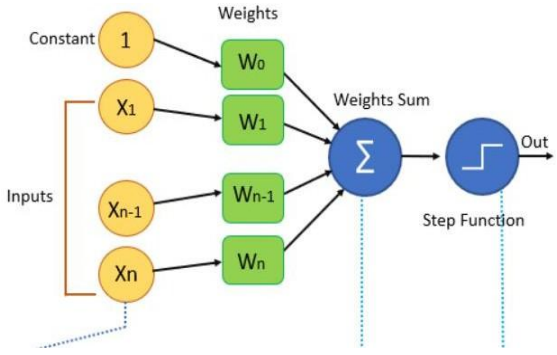

Fig 1: Perceptron Algorithm

Perceptron algorithms can be divided into two types: single layer perceptrons and multi-layer perceptrons.

How Neural Network Work?

Neural networks process data through multiple layers, where neurons transform input and produce an output. Their architecture mimics the human brain's decision-making, with neurons working together to handle complex data and generate predictions.

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The learning process enables neural networks to improve over time, refining their predictions as they receive more data. Input data enters the network, passes through multiple layers, and gets processed at each stage to generate the final output. The connections between neurons (called weights) determine how data is transferred from one neuron to another.

Learning in neural networks follows a structured, three-stage process:

- **Input Computation:** Data is fed into the network.
- **Output Generation:** Based on the current parameters, the network generates an output.
- **Iterative Refinement:** The network refines its output by adjusting weights and biases, gradually improving its performance on diverse tasks.

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:

$$z = w1x1 + w2x2 + \ldots + wnxn + b$$

where w represents the weights, x represents the inputs, and b is the bias.

Activation - The result of the linear transformation (denoted as z) 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.

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.

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.

Neural Network Architecture

Neural network architecture is organized into three main layers: the input layer, hidden layers, and output layer.

- **Input Layer**: This is where data is fed into the network. Each neuron in this layer stands for a feature or a piece of data.
- **Hidden Layers**: These layers process the data received from the input layer. The higher the number of hidden layers, the more depth the network has.

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- **Output Layer**: This layer, as the name suggests, is responsible for creating the final output of the network, such as a classification label or a predicted value.

How Neural Network Learn: The Training Process

1. Initially, the dataset should be fed into the input layer which will then flow to the hidden layer.
2. The connections which exist between the two layers randomly assign weights to the input.
3. A bias is added to each input. Bias is a constant which is used in the model to fit best for the given data.
4. The weighted sum of all the inputs will be sent to a function that is used to decide the active status of a neuron by calculating the weighted sum and adding the bias. This function is called the activation function.
5. The nodes that are required to fire for feature extraction are decided based on the output value of the activation function.
6. The final output of the network is then compared to the required labeled data of our dataset to calculate the final cost error. The cost error is actually telling us how 'bad' our network is. Hence we want the error to be as smallest as we can.
7. The weights are adjusted through backpropagation, which reduces the error. This backpropagation process can be considered as the central mechanism that neural networks learn. It basically fine-tunes the weights of the deep neural network in order to reduce the cost value.

In simple terms, what we do when training a neural network is usually calculating the loss (error value) of the model and checking if it is reduced or not. If the error is higher than the expected value, we have to update the model parameters, such as weights and bias values. We can use the model once the loss is lower than the expected error margin.

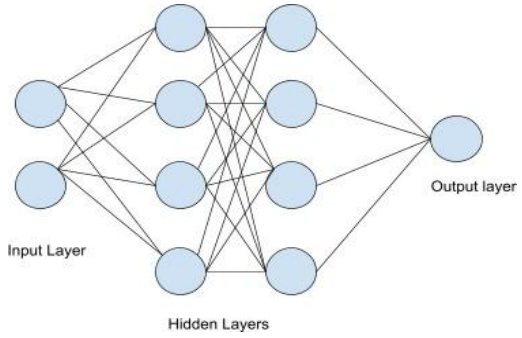

Fig 2: Neural Network Visualization

Neural networks can be described easily using the above diagram. The light blue circles represent the perceptrons, and the lines represent connections between artificial neurons.

When considering one perceptron, its job can be visualized as follows.

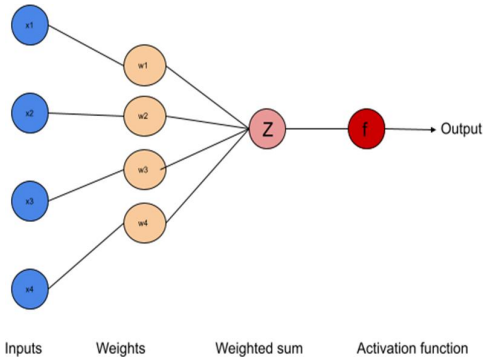

Fig 3: Job of single Perceptron

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When you input the data with random weights to the model, it generates the weighted sum of them. Understanding how a neural network works, according to that value, the activation function decides the activation status of the neuron. The output of this perceptron may act as an input for the next neuron layer.

Applications of Neural Network

Social Media: Artificial Neural Networks are used heavily in Social Media. For example, let's take the 'People you may know' feature on Facebook that suggests people that you might know in real life so that you can send them friend requests. Well, this magical effect is achieved by using Artificial Neural Networks that analyze your profile, your interests, your current friends, and also their friends and various other factors to calculate the people you might potentially know. Another common application of Machine Learning in social media is facial recognition. This is done by finding around 100 reference points on the person's face and then matching them with those already available in the database using convolutional neural networks.

Marketing and Sales: When you log onto E-commerce sites like Amazon and Flipkart, they will recommend your products to buy based on your previous browsing history. Similarly, suppose you love Pasta, then Zomato, Swiggy, etc. will show you restaurant recommendations based on your tastes and previous order history. This is true across all new-age marketing segments like Book sites, Movie services, Hospitality sites, etc., and it is done by implementing personalized marketing. This uses Artificial Neural Networks to identify the customer likes, dislikes, previous shopping history, etc., and then tailor the marketing campaigns accordingly.

Healthcare: Artificial Neural Networks are used in Oncology to train algorithms that can identify cancerous tissue at the microscopic level at the same accuracy as trained physicians. Various rare diseases may manifest in physical characteristics and can be identified in their premature stages by using Facial Analysis on the patient photos. So the full-scale implementation of Artificial Neural Networks in the healthcare environment can only enhance the diagnostic abilities of medical experts and ultimately lead to the overall improvement in the quality of medical care all over the world.

Personal Assistants: I am sure you all have heard of Siri, Alexa, Cortana, etc., and also heard them based on the phones you have!!! These are personal assistants and an example of speech recognition that uses Natural Language Processing to interact with the users and formulate a response accordingly. Natural Language Processing uses artificial neural networks that are made to handle many tasks of these personal assistants such as managing the language syntax, semantics, correct speech, the conversation that is going on, etc.

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