Artificial Neural Networks
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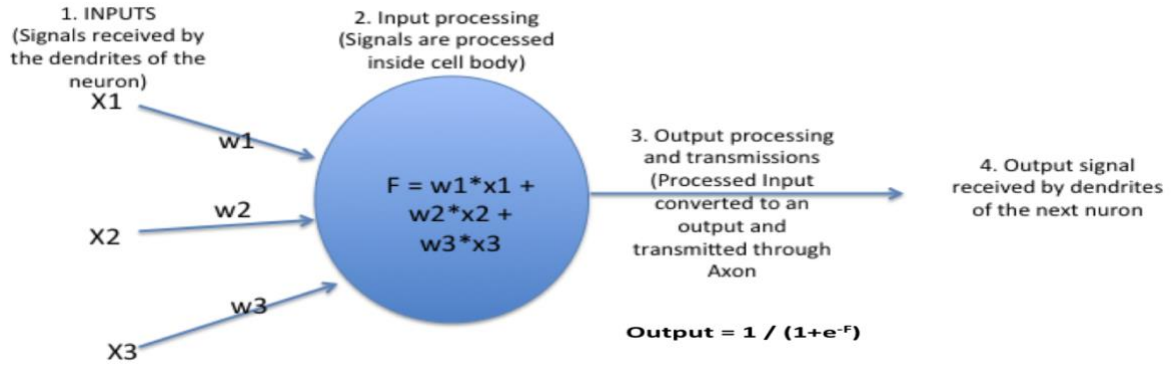
Overview

Neural networks are a set of algorithms, modeled loosely after the human brain, that are designed to recognize patterns. They interpret sensory data through a kind of machine perception, labeling or clustering raw input. The patterns they recognize are numerical, contained in vectors, into which all real-world data, be it images, sound, text or time series, must be translated.

The way neural network is very similar to the way brain works, in order to understand the working of neural networks we need to understand how a brain works. In our brain, there are billions of cells called neurons, which processes information in the form of electric signals. External information/stimuli is received by the dendrites of the neuron, processed in the neuron cell body, converted to an output and passed through the Axon to the next neuron. The next neuron can choose to either accept it or reject it depending on the strength of the signal. The way neural networks work is very similar to how neurons in our brain works.



Neural networks help us cluster and classify. You can think of them as a clustering and classification layer on top of the data you store and manage. They help to group unlabeled data according to similarities among the example inputs, and they classify data when they have a labeled dataset to train on neural networks can also extract features that are fed to other algorithms for clustering and classification; so you can think of deep neural networks as components of larger machine-learning applications involving algorithms for reinforcement learning, classification and regression

History

A traditional digital computer does many tasks very well. It's quite fast, and it does exactly what you tell it to do. Unfortunately, it can't help you when you yourself don't fully understand the problem you want solved. Even worse, standard algorithms don't deal well with noisy or incomplete data, yet in the real world, that's frequently the only kind available. One answer is to use an artificial neural network, a computing system that can learn on its own.

The first artificial neural network was invented in 1958 by psychologist Frank Rosenblatt. Called Perceptron, it was intended to model how the human brain processed visual data and learned to recognize objects.

How do Neural Networks learn?

Neural networks with their deep learning cannot be programmed directly for the task. Rather, they have the requirement, just like a child's developing brain, that they need to learn the information. The learning strategies go by three methods:

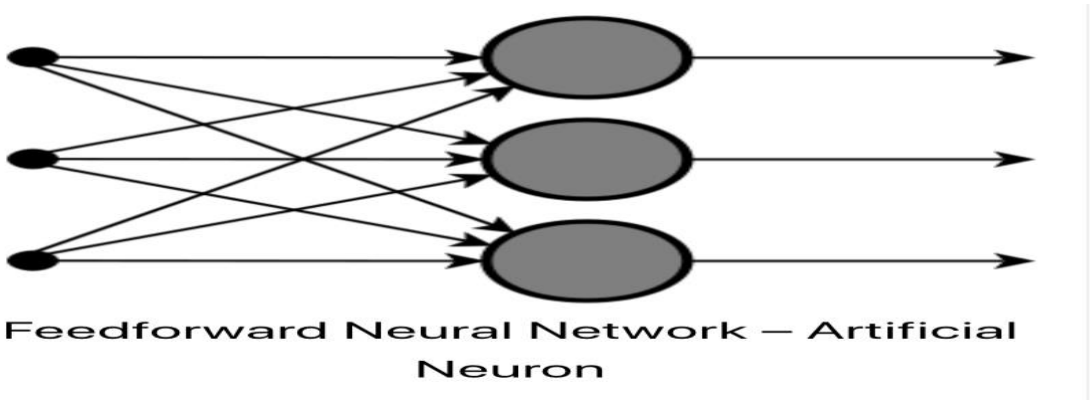
- **Supervised learning:** This learning strategy is the simplest, as there is a labeled dataset, which the computer goes through, and the algorithm gets modified until it can process the dataset to get the desired result.
- **Unsupervised learning:** This strategy gets used in cases where there is no labeled dataset available to learn from. The neural network analyzes the dataset, and then a cost function then tells the neural network how far off of target it was. The neural network then adjusts to increase accuracy of the algorithm.
- **Reinforced learning:** In this algorithm, the neural network is reinforced for positive results, and punished for a negative result, forcing the neural network to learn over time.

Types of Artificial Neural Networks

Different types of neural networks use different principles in determining their own rules. There are many types of artificial neural networks, each with their unique strengths.

Feedforward Neural Network

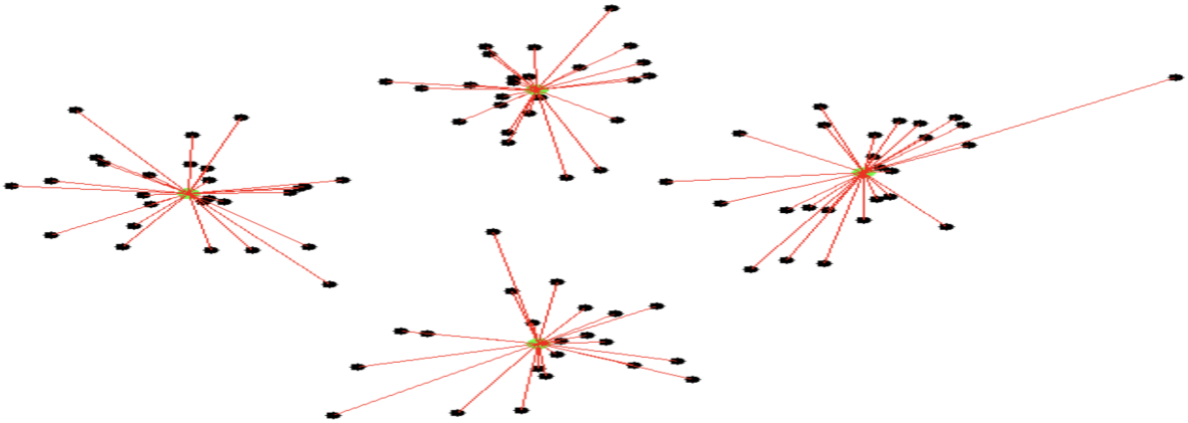
- This is one of the simplest types of artificial neural networks. In a feedforward neural network, the data passes through the different input nodes till it reaches the output node.
- In other words, data moves in only one direction from the first tier onwards until it reaches the output node. This is also known as a front propagated wave which is usually achieved by using a classifying activation function.
- Unlike in more complex types of neural networks, there is no backpropagation and data moves in one direction only. A feedforward neural network may have a single layer or it may have hidden layers.
- In a feedforward neural network, the sum of the products of the inputs and their weights are calculated. This is then fed to the output.
- Feedforward neural networks are used in technologies like face recognition and computer vision. This is because the target classes in these applications are hard to classify.
- A simple feedforward neural network is equipped to deal with data which contains a lot of noise. Feedforward neural networks are also relatively simple to maintain.



Feedforward Neural Network — Artificial Neuron

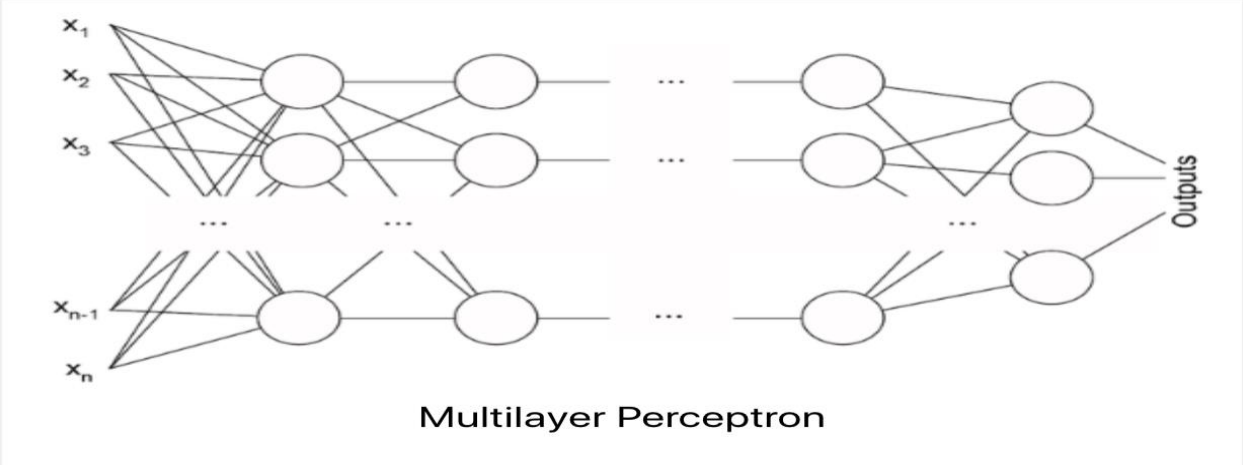
Radial basis Function Neural Network

- A radial basis function considers the distance of any point relative to the center. Such neural networks have two layers. In the inner layer, the features are combined with the radial basis function.
- Then the output of these features is taken into account when calculating the same output in the next time-step.
- The radial basis function neural network is applied extensively in power restoration systems. In recent decades, power systems have become bigger and more complex.
- This increases the risk of a blackout. This neural network is used in the power restoration systems in order to restore power in the shortest possible time.



Multilayer Perceptron

- A multilayer perceptron has three or more layers. It is used to classify data that cannot be separated linearly. It is a type of artificial neural network that is fully connected. This is because every single node in a layer is connected to each node in the following layer.
- A multilayer perceptron uses a nonlinear activation function (mainly hyperbolic tangent or logistic function).
- This type of neural network is applied extensively in speech recognition and machine translation technologies.



Multilayer Perceptron

Convolutional Neural Networks

- A convolutional neural network(CNN) uses a variation of the multilayer perceptrons. A CNN contains one or more than one convolutional layers. These layers can either be completely interconnected or pooled.
- Before passing the result to the next layer, the convolutional layer uses a convolutional operation on the input. Due to this convolutional operation, the network can be much deeper but with much fewer parameters.
- Due to this ability, convolutional neural networks show very effective results in image and video recognition, natural language processing, and recommender systems.
- Convolutional neural networks also show great results in semantic parsing and paraphrase detection. They are also applied in signal processing and image classification.
- CNNs are also being used in image analysis and recognition in agriculture where weather features are extracted from satellites like LSAT to predict the growth and yield of a piece of land.

There are many types of artificial neural networks that operate in different ways to achieve different outcomes. The most important part about neural networks is that they are designed in a way that is similar to how neurons in the brain work. As a result, they are designed to learn more and improve more with more data and more usage. Unlike traditional machine learning algorithms which tend to stagnate after a certain point, neural networks have the ability to truly grow with more data and more usage.

Advantages of Artificial Neural Networks

- **Storing information on the entire network**: Information such as in traditional programming is stored on the entire network, not on a database. The disappearance of a few pieces of information in one place does not restrict the network from functioning.
- **The ability to work with inadequate knowledge**: After ANN training, the data may produce output even with incomplete information. The lack of performance here depends on the importance of the missing information.
- **It has fault tolerance**: Corruption of one or more cells of ANN does not prevent it from generating output. This feature makes the networks fault-tolerant.
- **Having a distributed memory**: For ANN to be able to learn, it is necessary to determine the examples and to teach the network according to the desired output by showing these examples to the network. The network's progress is directly proportional to the selected instances, and if the event cannot be shown to the network in all its aspects, the network can produce incorrect output
- **Gradual corruption**: A network slows over time and undergoes relative degradation. The network problem does not immediately corrode.
- **Ability to train machine**: Artificial neural networks learn events and make decisions by commenting on similar events.
- **Parallel processing ability**: Artificial neural networks have numerical strength that can perform more than one job at the same time.

Disadvantages of Artificial Neural Networks

- **Hardware dependence**: Artificial neural networks require processors with parallel processing power, by their structure. For this reason, the realization of the equipment is dependent.
- **Unexplained functioning of the network**: This is the most important problem of ANN. When ANN gives a probing solution, it does not give a clue as to why and how. This reduces trust in the network.
- **Assurance of proper network structure**: There is no specific rule for determining the structure of artificial neural networks. The appropriate network structure is achieved through experience and trial and error.
- **The difficulty of showing the problem to the network**: ANNs can work with numerical information. Problems have to be translated into numerical values before being introduced to ANN. The display mechanism to be determined here will directly influence the performance of the network. This depends on the user's ability.
- **The duration of the network is unknown**: The network is reduced to a certain value of the error on the sample means that the training has been completed. This value does not give us optimum results.

Applications of Neural Networks

Most of the artificial Neural Networks applications fall under three categories:

- Classification
- Time Series
- Control and Optimization

1. Image Processing and Character recognition: Given Artificial Neural Networks ability to take in a lot of inputs, process them to infer hidden as well as complex, non-linear relationships, ANNs are playing a big role in image and character recognition. Character recognition like handwriting has lot of applications in fraud detection (e.g. bank fraud) and even national security assessments. Image recognition is an ever-growing field with widespread applications from facial recognition in social media, cancer detention in medicine to satellite imagery processing for agricultural and defense usage. The research on ANN now has paved the way for deep neural networks that forms the basis of "deep learning" and which has now opened up all the exciting and transformational innovations in computer vision, speech recognition, natural language processing famous examples being self-driving cars.

2. Forecasting: Forecasting is required extensively in everyday business decisions (e.g. sales, financial allocation between products, capacity utilization), in economic and monetary policy, in finance and stock market. More often, forecasting problems are complex, for example, predicting stock prices is a complex problem with a lot of underlying factors (some known, some unseen). Traditional forecasting models throw up limitations in terms of taking into account these complex, non-linear relationships. ANNs, applied in the right way, can provide robust alternative, given its ability to model and extract unseen features and relationships. Also, unlike these traditional models, ANN doesn't impose any restriction on input and residual distributions.

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