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Artificial Neural Networks

***V. Rajeswari, S. Brindha**
Marudhar Kesari Jain College for Women, Vaniyambadi, Tamil Nadu, India.
*Corresponding author Email: srsurajvarsi@gmail.com

Abstract. Artificial neural networks (ANNs) were designed to simulate the biological nervous system, where information is sent via input signals to a processor, resulting in output signals. ANNs are composed of multiple processing units that work together to learn, recognize patterns, and predict data.
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1. Introduction

The term "Artificial neural network" refers to a biologically inspired sub-field of artificial intelligence modeled after the brain. An Artificial neural network is usually a computational network based on biological neural networks that construct the structure of the human brain. Similar to a human brain has neurons interconnected to each other, artificial neural networks also have neurons that are linked to each other in various layers of the networks. These neurons are known as nodes. What is Artificial Neural Network. The term "Artificial Neural Network" is derived from Biological neural networks that develop the structure of a human brain. Similar to the human brain that has neurons interconnected to one another, artificial neural networks also have neurons that are interconnected to one another in various layers of the networks. These neurons are known as nodes. [1] Dendrites from Biological Neural Network represent inputs of Artificial Neural Networks, cell nucleus represents Nodes, synapse represents Weights, and Axon represents Output.

TABLE 1. Relationship between Biological neural network and artificial neural network

Biological Neural Network	Artificial Neural Network
Dendrites	Inputs
Cell nucleus	Nodes
Synapse	Weights
Axon	Output

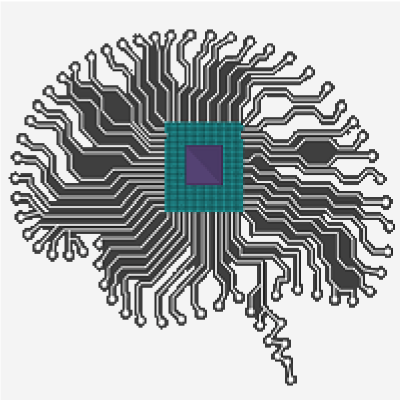

FIGURE 1. Artificial Neural Network

An Artificial Neural Network in the field of Artificial intelligence where it attempts is to mimic the network of neurons makes up a human brain so that computers will have an option to understand things and make decisions in a human-like manner. The artificial neural network is designed by programming computers to behave simply like interconnected brain cells. There are around 1000 billion neurons in the human brain. Each and every neuron has an association point somewhere in the range of 1,000 and 100,000. In the human brain, data is stored in such a manner as to be distributed, and we can extract more than one piece of this data, when necessary, from our memory parallelly. We can say that the human brain is made up of incredibly amazing parallel processors. We can understand the artificial neural network with an example, consider an example of a digital logic gate that takes an input and gives an output. "OR" gate, which takes two inputs. If one or more the inputs are "On," then we get "On" in output. If both the inputs are "Off," then we get "Off" in output. Here the output depends upon input. Our brain does not perform the same task. The outputs to inputs relationship keep changing because of the neurons in our brain, which are "learning". What is a neural network In Information technology (IT), an artificial neural network (ANN) is a system of hardware and/or software patterned after the operation of neurons in the human brain. ANNs also called, simply, neural networks are a variety of deep learning technology, which also falls under the umbrella of artificial intelligence, or

2. AI Types of neural networks

Neural networks are sometimes described in terms of their depth, including how many layers they have between input and output, or the models. So, it is called hidden layers. This is why the term *neural network* is used almost synonymously with deep learning. They can also be described by the number of hidden nodes the model has or in terms of how many inputs and outputs each node has. Variations on the classic neural network design allow various forms of forward and backward propagation of information among tiers. Specific types of artificial neural networks include: Feed-forward neural networks: One of the simplest variants of the neural networks. They pass information in one direction, through various input nodes, until it makes it to the output node. The network may or may not have hidden node layers, making their functioning more interpretable. It is prepared to process large amount of noise. This type of ANN computational model is used in the technologies such as facial recognition and computer vision. Recurrent neural networks: More complex network. They save the output of processing nodes and feed the result back into the model. This is how the model is said to learn to predict the outcome of a layer. Each node in the RNN model acts as a memory cell, continuing the computation and implementation of operations. This neural network starts with the same front propagation as a feed-forward network, but then goes on to remember all processed information in order to reuse it in the future. If the network's prediction is incorrect, then the system self-learns and continues working towards the correct prediction during backpropagation. This type of ANN is frequently used in text-to-speech conversions. Convolutional neural networks: One of the most popular models used today. This neural network computational model uses a variation of multilayer perceptron's and contains one or more convolutional layers that can be either entirely connected or pooled. These convolutional layers create feature maps that record a region of image which is ultimately broken into rectangles and sent out for nonlinear The CNN model is particularly popular in the realm of image recognition; it has been used in many of the most advanced applications of AI, including facial recognition, text digitization and natural language processing. Other uses include paraphrase detection, signal processing and image classification. Deconvolutional neural networks: Utilize a reversed CNN model process. They aim to find lost features or signals that may have originally been considered unimportant to the CNN system's task. This network model can be used in image synthesis and analysis. Modular neural networks: Contain multiple neural networks working separately from one another. The networks do not communicate or interfere with each other's activities during the computation process. Consequently, complex or big computational processes can be performed more efficiently. Advantages of artificial neural networks Advantages of artificial neural networks include: Parallel processing abilities mean the network can perform more than one job at a time. Information is stored on an entire network, not just a database. The ability to learn and model nonlinear, complex relationships helps model the real-life relationships between input and output. Fault tolerance means the corruption of one or more cells of the ANN will not stop the generation of output. Gradual corruption means the network will slowly degrade over time, instead of a problem destroying the network instantly. The ability to produce output with incomplete knowledge with the loss of performance being based on how important the missing information is. No restrictions are placed on the input variables, such as how they should be distributed. Machine learning means the ANN can learn from events and make decisions based on the observations. The ability to learn hidden relationships in the data without commanding any fixed relationship means an ANN can better model highly volatile data and non-constant variance. The ability to generalize and infer unseen relationships on unseen data means ANNs can predict the output of unseen data. Disadvantages of artificial neural networks the disadvantages of ANNs include: The lack of rules for determining the proper network structure means the appropriate artificial neural network architecture can only be found through trial and error and experience. The requirement of processors with parallel processing abilities makes neural networks hardware-dependent. The network works with numerical information; therefore, all problems must be translated into numerical values before they can be presented to the ANN. The lack of explanation behind probing solutions is one of the biggest disadvantages in ANNs. The inability to explain the why or how behind the solution generates a lack of trust in the network. The architecture of an artificial neural network: To understand the concept of the architecture of an artificial neural network, we have to understand what a neural network consists of. In order to define a neural network that consists of a large number of artificial neurons, which are termed units arranged in a sequence of layers. Let us look at various types of layers available in an artificial neural network. Artificial Neural Network primarily consists of three layers:

$$\sum_{i=1}^{n} Wi * Xi + b$$

Input Layer: As the name suggests, it accepts inputs in several different formats provided by the programmer. Hidden Layer: The hidden layer presents in-between input and output layers. It performs all the calculations to find hidden features and patterns. Output Layer: The input goes through a series of transformations using the hidden layer, which finally results in output that is conveyed using this layer. The artificial neural network takes input and computes the weighted sum of the inputs and includes a bias. This computation is represented in the form of a transfer function.

It determines weighted total is passed as an input to an activation function to produce the output. Activation functions choose whether a node should fire or not. Only those who are fired make it to the output layer. There are distinctive activation functions available that can be applied upon the sort of task we are performing.

3. ANN Working

The input node takes the information in numerical form. The information represents an activation value where each node has given a number. The higher the number, the greater the activation. Based on weights and activation function, the activation value passes to the next node. Each node calculates the weighted sum and updates that sum based on the transfer function (activation function). After that, it applies an activation function. This function applies to this particular neuron. From that, the neuron concludes if it needs to forward the signal or not. ANN decides the signal extension on the adjustments of the weights. The activation runs through the network until it reaches the output node. The output layer shares the information in an understanding way. The network uses the cost function to compare the output and expected output. Cost function refers to the difference between the actual value and the predicted value. Lower the cost function, closer it is to the desired output. There are two processes for minimizing the cost function. Back Propagation: Back propagation is the core of neural network training. It is the prime mechanism by which neural networks learn. Data enters the input layer and propagates in the network to give the output. After that, the cost function will equate the output and desired output. If the value of the cost function is high then the information goes back, and the neural network starts learning to reduce the cost function by adjusting the weights. Proper adjustment of weights lowers the error rate and makes the model definitive. Forward Propagation: The information enters into the input layer and forwards in the network to get the output value. The user compares the value to the expected results. The next step is calculating errors and propagating the information backward. This permits the user to train the neural network and modernize the weights. Due to the structured algorithm, the user can adjust weights simultaneously. It will help the user to see which weight of the neural network is responsible for error. Types of Artificial Neural Network 1) Feedforward Network This network contains an input, hidden, and output layer. Signals can move in only one direction. Input data passes to the hidden layer to perform the mathematical calculations. Processing element computes according to the weighted sum of its inputs. The output of the previous layer becomes the input of the following layer. This continues through all the layers and determines the output. Eg: Data mining Feedback network This network has feedback paths. It means signals can travel in both the direction using loops. Neurons can have all the possible connections. Due to loops, it becomes a dynamic system that changes continuously to reach in the equilibrium state. Eg: Recurrent neural network

4. ANN Learning Techniques

Supervised Learning: The user trains the model using labelled data. It means some data is already marked with the correct answers. Supervised learning can be compared to the learning which is held in the presence of a supervisor. Unsupervised learning: The model does not need supervision. It usually deals with the unlabelled data. User permits the model to work on its own to classify the data. It sorts the data according to the similarities and patterns without any prior training to the data. Artificial Neural Network Applications Text classification and specialization: It is an essential part of many applications like web searching, information filtering, and language identification. Medical We can use it in detecting cancer cells and analyzing the MRI images to give detailed results. Paraphrase detection Question answering system needs to determine whether two sentences have the same meaning or not. Artificial neural networks are very helpful in paraphrasing detection. Forecast We can use it in every field of business decisions like in finance and the stock market, in economic and monetary policy. Image processing: We can use satellite imagery processing for agricultural and defense use. Handwriting recognition with Neural Networks Handwriting and facial recognition using neural networks does the same thing, meaning making a series of binary decisions. This is because any image can be broken down into its smallest object, the pixel. In the case of handwriting, like shown below, each pixel is either black (1) or white (meaning empty, or 0). .Image Recognition with Neural Networks Already we introduced the concept of perceptrons, which take inputs from simple linear equations and output 1 (true) or 0 (false). They are the left-hand side of the neural network. But as Michael Nielsen explains, perceptrons are not suitable for tasks like image recognition because small changes to the weights and biases product large changes to the output. After all, going to 0 to 1 is a large change. It would be better to go from, say, 0.6 to 0.65. Suppose have a simple neural network with two input variables x1 and x2 and a bias of 3 with weights of -2 and -3. The equation for that is: If $-2\times1 + -3\times2 + 3 < 0$ then 1 (true) otherwise 0 (false). (That's not exactly the correct way to express that in algebra, but it is close enough. The goal here is to keep the math to a minimum to make it easier to understand. Michael's paper is difficult to understand for those without a math background.) Machine learning adjusts the weights and the biases until the resulting formula most accurately calculates the correct value. Remember from the last post, that this is the same as saying that adjusting the weights and biases reduces the loss function to its minimum. Most ML problems work that way. For example, linear regression. So how do we avoid the large change of going from 0 to 1, which would mess up our model? We allow inputs and output numbers between 0 and 1 instead of just 0 or 1. The simplest way to do that is to divide the equation into the number 1, by using a similar formula, as that used by logistic regression. And then we adopt the convention that if the final output value of the neural network has a threshold, say 0.5, then we can conclude that the outcome is 1. But isn't that just a roundabout way of calculating something that results in either 0 or 1? No. Because in a neural network there is not just the input initial values and the resulting output. In the middle, there are intermediate steps called hidden layers. Those need not evaluate to 0 or 1.

(You can play around with a neural network to add or remove hidden layers using this online tool.) To illustrate, let z=x1w1 + x2w2 + b be the function above. Then we create a modified perception called a sigmoid neuron function (δ) like this.

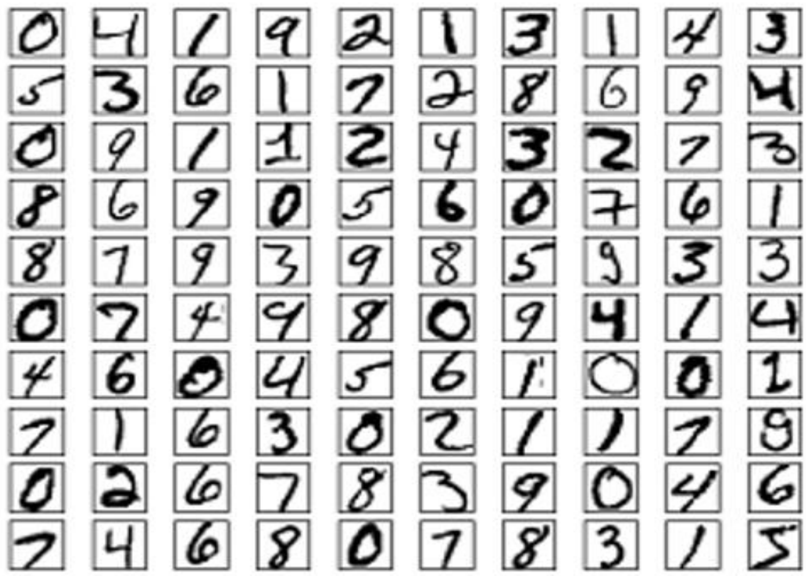

FIGURE 2. Recognition with Neural Networks

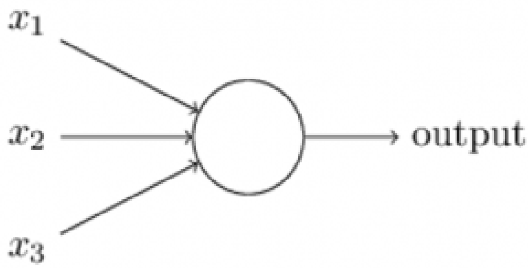

FIGURE 3. output

$$\frac{1}{1+\exp(-z)}$$

Now we state that the values of x1 and x2 in function z do not have to be integers. They can be any value between 0 and 1, as a result of which the sigmoid neuron function δ will vary between 0 and 1. Remember that exp, the constant e = 2.714. Raising it to a negative power is the same as dividing it into 1, i.e. exp (-z) = 1 / exp (z). When the value of z is large then exp (-z) is small (close to zero). Because 1 divided by something large is small. In that case, the sigmoid neuron function is close to 1. Conversely, when z is small then 1/ (1 + exp (-z) is close to 0. But for values that are neither large nor small, δ does not vary much.

5. Conclusion

Artificial neural networks are powerful models to solve the problems. Mostly, neural network methods exceed other methods.

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