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APPLICATION OF ARTIFICIAL NEURAL NETWORK (ANN): AN INNOVATION TO ENGINEERING, SCIENCE AND TECHNOLOGY

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Abstract
Neural networks have proven to be effective mapping tools for a wide variety of problems and consequently they have been used extensively by practitioners in almost every application domain ranging from agriculture to zoology (a-z). Since neural networks are best at identifying patterns or trends in data, they are well suited for prediction or forecasting applications. The intention of this paper is to introduce a brief overview of neural network (NN) techniques, Types of Neural Networks, basic concept of its modeling development and applications.
Key words: Feedforward, Neural Network, Neuron, Perceptron, Recurrent

Introduction

Artificial Neural Network (ANN) is defined as a data processing system consisting of a large number of simple highly inter connected processing elements (artificial neurons) in an architecture inspired by the structure of the cerebral cortex of the brain. The terminology of artificial neural networks has developed from a biological model of the brain (Kumar, Raghuwanshi, Singh, Wallender and Pruirt, 2002). A neural network consists of a Set of connected cells: The neurons receive impulses from either input cells or other neurons and perform some kind of transformation of the input and transmit the outcome to other neurons or to output cells. The neural networks (NNs) are built from layers of neurons connected so that one layer receives input from the preceding layer of neurons and passes the output on to the subsequent layer.

Neural Networks Architectures

There are several types of architecture of NNs. However, the two most widely used NNs are the Feedforward networks and the Recurrent networks.

Feedforward network

A Feedforward Neural Network is a type of artificial neural network that can autonomously learn from input data to perform specific tasks, such as image classification. It predicts the classification label of a given image by mapping the input data to a vector of scores (prediction probabilities) for each classification label. The label with the highest score is considered the predicted category. The network's performance depends on the weights and biases assigned to its connections (Xichuan Zhou, Haijun Liu, Cong Shi, Ji Liu, 2022).

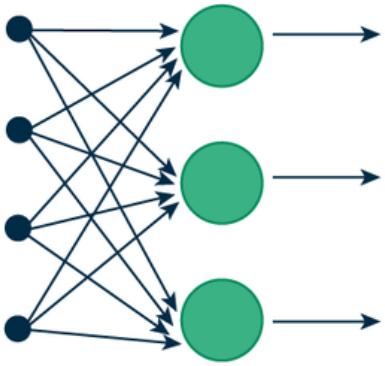


Fig.1 Feedforward Neural Network

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Given in figure 1 is an example of a feedforward Neural Network. It is a directed acyclic Graph which means that there are no feedback connections or loops in the network. It has an input layer, an output layer, and a hidden layer. In general, there can be multiple hidden layers. Each node in the layer is a Neuron, which can be thought of as the basic processing unit of a Neural Network (vikas, 2017).

In a feed forward network, information flows in one direction along connecting pathways, the input layer through the hidden layers to the final output layer (Kohzadi, Boyd, Kermanshashi, and Kaastra, 1996). There is no feedback (loops) i.e., the output of any layer does not affect that same or preceding layer.

Recurrent network

Recurrent neural networks **(**RNNs), on the other hand, are designed to recognize patterns in sequences of data. They have a "memory" that captures information about what has been calculated so far. This memory allows RNNs to use prior inputs to influence the current output. (Rishabh, 2024)

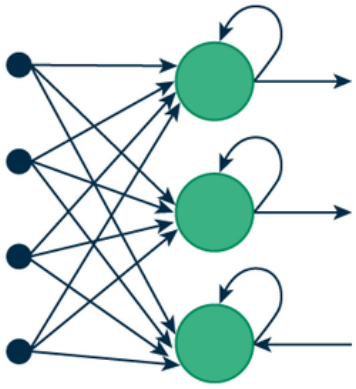


Fig 2: Recurrent Neural Network

Recurrent networks differ from feed forward network architectures in the sense that there is at least one feedback loop. Thus, in these networks, for example, there could exist one layer with feedback connections. There could also be neurons with self-feedback links, i.e. the Output of a neuron is fed back, into itself as input.

Basic Concept of Artificial Neural Network

The basic concept behind the successful application of neural networks in any field is to determine the weights to achieve the desired target and this process is called learning or training. The three different learning mechanisms usually employed are supervised, unsupervised and reinforced learning.

Supervised learning

In the case of supervised learning the network weights are modified with the prime objective of minimization of the error between a given set of inputs and their corresponding target values (Tarafdar, Haque and Kashtiban, 2005). Hence we know the training data set which is a set of inputs and the corresponding targets the neural network should output ideally. This is called supervised learning because both the inputs and the expected target values are known prior to the training of ANN.

Unsupervised learning

On the other hand, in the case of unsupervised learning, the relationship the inputs and the target values are not known. The neural network is trained with a training data set 'which only the input values are known. Hence it is very important to choose the right set 'of examples for efficient training. These examples are usually chosen using some sort of a 'similarity principle (Tarafdar, Haque and Kashtiban, 2005). The most commonly used unsupervised learning algorithms are the Self-Organizing Map (SOM) and the Adaptive Resonance Theory (ART).

Reinforced learning

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In this method, a teacher though available, does not present the expected answer but only indicates if the computed output is correct or incorrect. The information provided helps the network in its learning process. A reward is given for a correct answer computed and a penalty for a wrong answer. But, reinforced learning is not one of the popular forms of learning. The learning strategy employed, depends on the structure of the neural network.

Types of Neural Networks

The most important class of neural networks for real world problems solving are:

- Multilayer Perceptron
- Radial Basis Function Networks
- Kohonen Self Organizing Feature Maps

Multilayer Perceptron

The most popular form of neural network architecture is the multilayer perceptron (MLP). Given enough data, enough hidden units, and enough training time, an MLP with just one hidden layer can learn to approximate virtually any function to any degree of accuracy. (A statistical analogy is approximating a function with nth order polynomials.) For this reason, are known as universal approximators and can be used when you have little prior knowledge of the relationship between inputs and targets. Although one hidden layer is always sufficient provided you have enough data, there are situations where a network with two or more hidden layers may require fewer hidden units and weights than a network with tone hidden layer, so using extra hidden layers sometimes can improve generalization.

Radial basis function networks

Radial basis functions (RBF) networks are also feed forward, but have only one hidden layer. While MLPs are said to be distributed-processing networks because the effect of a hidden unit can be distributed over the entire input space, RBF networks are said to be local-processing networks because the effect of a hidden unit is usually concentrated in a local area centered at the weight vector.

Kohonen self organizing feature map

Self-Organizing Feature Map (SOFM, or Kohonen) networks are used quite differently to the other networks. Whereas all the other networks are designed for supervised learning tasks, SOFM networks are designed primarily for unsupervised learning (Lipmann, 1989). At first glance this may seem strange. Without outputs, what can the network learn? The answer is that the SOFM network attempts to learn the structure of the data. One possible use is therefore in exploratory data analysis. A second possible use is in novelty detection.

SOFM networks can learn to recognize clusters in the training data, and respond to it. If new data, unlike previous cases, is encountered, the network fails to recognize it and this indicates novelty. A SOFM network has only two layers: the input layer, and an output layer of radial units (also known as the topological map layer).

Development of an ANN model

The various steps in developing a neural network model are: Variable Selection, formation of training/ validation sets, Neural Network architecture, Evaluation Criteria and Neural Network testing.

- **Variable selection**

The input variables are important for modeling variable(s) under study are selected by suitable variable selection procedures.

- **Formation of training, testing and validation sets**

The data set is divided into three distinct sets called training, testing and validation sets, The training set is the

largest set and is used by neural network to learn patterns present in the data. The testing set is used to evaluate the generalization ability of a supposedly trained network. A final check on the performance of the trained network is made using validation set.

- **Neural network architecture**

Neural network architecture defines its structure including number of hidden layers, number of hidden nodes and number of output nodes, etc (Hagan, Demuth, Beale, 1996).

• Number of hidden layers: The hidden layer(s) provide the network with its ability to generalize. In theory, a neural network with one hidden layer with a sufficient number of hidden neurons is capable of approximating any continuous function. In practice, neural network with one and occasionally two hidden layers are widely used and have to perform very well.

• Number of hidden nodes: There is no magic formula for selecting the optimum number of hidden neurons. However, some thumb rules are available for calculating number of hidden neurons. A rough approximation can be obtained by the geometric pyramid rule ' proposed by (Master, 1993). For a three-layer network with n input and m output neurons, the hidden layer would have sqrt(n*m) neurons.

• Number of output nodes: Neural networks with multiple outputs, especially if these outputs are widely spaced, will produce inferior results as compared to a network with a single output.

• Activation function: As aforementioned, activation functions are mathematical formulae that determine the output of a processing node. Each unit takes its net input and applies an activation function to it. Non-linear functions have been used as activation functions such as logistic, tan h etc. The purpose of the transfer function is to prevent output from reaching very large value which can 'paralyze' neural networks and thereby inhibit training. Transfer functions such as sigmoid are commonly used because they are nonlinear and continuously differentiable which are desirable for network learning.

- **Evaluation Criteria**

The most common error function minimized in neural networks is the sum of squared errors, r error functions offered by different software include least absolute deviations, least fourth powers, asymmetric least squares and percentage differences.

- **Neural Network Training**

Training a neural network to learn patterns in the data involves iteratively presenting it with examples of the correct known answers. The objective of training is to find the set of weights the neurons that determine the global minimum of error function. This involves decision regarding the number of iteration i.e., when to stop training a neural network and the selection of learning rate (a constant of proportionality which determines the size of the weight adjustments made at each iteration) and momentum values (how past weight changes affect current weight changes).

Neural Networks based Software

Several neural networks based softwares, have been developed, some of which include;

Commercial Software: Statistica Neural Network, TNs2Server, DataEngine, Know Man Basic Suite, Partek, Saxon, ECANSE - Environment for Computer Aided Neural Software Engineering, Neuroshell, Neurogen, Matlab:Neural Network Toolbar.

Freeware Software: Net II, Spider Nets Neural Network Library, NeuDC, Binary Hopfeild with free Java source, Neural shell, PlaNet, Valentino Computational Neuroscience work bench, Neural Simulation language version-NSL, Brain neural network Simulator.

Conclusion

The computing world has a lot to gain from neural networks. Their ability to learn by example makes them very flexible and powerful. A large number of claims have been made about the filing capabilities of neural networks, some exaggerated and some justified. Hence, to best utilize ANNs for different problems, it is

essential to understand the potential as well as limitations of neural networks. For some tasks, neural networks will never replace methods, but for a growing list of applications, the neural architecture will provide either an alternative or a complement to these existing techniques.

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