www.ijecs.in
International Journal Of Engineering And Computer Science ISSN:2319-7242
Volume 4 Issue 1 January 2015, Page No. 9868-9873

Introduction to technique of Soft Computing: Artificial Neural Networks

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Abstract:***This is a literature survey on one of the soft computing techniques i.e. neural networks. It is aimed to get a general understanding on neural networks and find out the possible applications of these models. Beginning with a preliminary definition and typical structure of neural networks, neural networks are studied with respect to their architecture structures.***
The characteristics and applications of some neural network models are then discussed.

Keywords: Neural Network, Neuron, Neural Network Architecture.

Introduction

Artificial intelligence (AI) is an area of computer science concerned with designing intelligent computer systems that is, systems that exhibit the characteristics that associate with intelligence in human behavior. Lotfi Zadeh [1], father of fuzzy logic, has classified computing as hard computing and soft computing [2]. The computations based on Boolean algebra and other crispy numerical computations are defined as hard computing, whereas fuzzy logic, neural network and probabilistic reasoning techniques, such as genetic algorithm and parts of learning theory are categorized as soft computing. Soft computing differs from conventional (hard) computing in that, unlike hard computing, it is tolerant of imprecision, uncertainty and partial truth. Soft computing is more analogous to thinking of human mind [1-12]. Hard computing methods are predominantly based on mathematical approaches & therefore demand a high degree of precision & accuracy in their requirements. But in most engineering problems, the input parameters cannot be determined with a high degree of precision & therefore, the best estimates of the parameters used for obtaining solutions to problems. Soft computing techniques, which have drawn their inherent characteristics from biological systems, present effective methods for the solution of even difficult inverse problems. Neural network are simplified model of the biological nervous system. Therefore it has drawn their motivation from the kind of computing performed by a human brain.

An NN, in general is a highly interconnected network of a large number of processing elements called neurons in an architecture developed by the brain. NN exhibit characteristics such as mapping capabilities or pattern association, generalization, robustness, fault tolerance, & parallel & high speed information processing. NN learned by examples. They can be trained with known examples of a problem to 'acquire' knowledge about it. Once appropriately trained, the network can be put to effective use in solving 'unknown' or 'untrained' instances of the problem. Neural networks adopt various learning mechanisms of which supervised learning & unsupervised leaning methods have turned out to be very popular. In supervised learning a 'teacher' is assumed to be present during learning process whereas in unsupervised learning there is no 'teacher'. NN architectures have been broadly classified as single layer feedforward networks, multilayer feedforward networks & recurrent networks.

Some of the well known NN systems include backpropagation network perceptron, ADALINE, associative memory, adaptive resonance theory, self-organizing feature map, Boltzmann machine & Hopfield network. Neural networks have been successfully applied to problems in the fields of pattern recognition, image processing, data compression, forecasting, & optimization to quote a few.

1. Basic Concepts of Neural Networks

Neural networks, which are simplified models of the biological neuron system. Derives it's origin from human brain. It is a massively parallel distributed processing system made up of highly interconnected neural computing elements. The elements have the ability to learn and thereby acquire knowledge and make it available for use. NNs are simplified imitations of the central nervous system. Therefore it have been motivated by the kind of computing performed by the human brain. Neurons perform computations such as cognition, logical inference, pattern recognition and so on. Hence the technology, which has been built on a simplified imitation of computing by neurons of a brain, has been termed Artificial Neural Systems technology or Artificial Neural Networks or simply Neural Networks. Also neurons are referred to as neurodes, Processing Elements (PEs), and nodes.

2. Human Brain

The human brain is one of the most complicated things which, on the whole, has been poorly understood. However the concept of neurons as the fundamental constituent of the brain, attributed to Ramon Y.Cajal(1911), has made the study of its functioning comparatively easier. Brain has a highly complex, nonlinear & parallel computing. Brain contains about 10^{10} basic units called neurons. Each neuron in turn, is connected about 10^{4} other neurons. A neuron is a small c that receives electro-chemical signals from its various sources and in turn responds by transmitting electrical impulses to other neurons.

X_n

An average brain weighs about 1.5kg and an average neuron has a weight of 1.5×10^{-9} gms. While some of the neurons perform input and output operations. A neuron is composed of a nucleus a cell body known as *soma* shown in figure 2.Attached to the soma are long irregularly shaped filaments called *dentrites*. The dentrites behave as input channels,(i.e) all inputs from other neurons arrive through the dentrites. Another type of link attached to the soma is Axon. Unlike dendrites links, the axon is electrically active and serves as an output channel. The axon terminates in a specialized contact called synapse or synaptic junction. The synapse connects the axon with the dendritic links of another neuron. A single neuron can have many synaptic inputs and synaptic outputs.

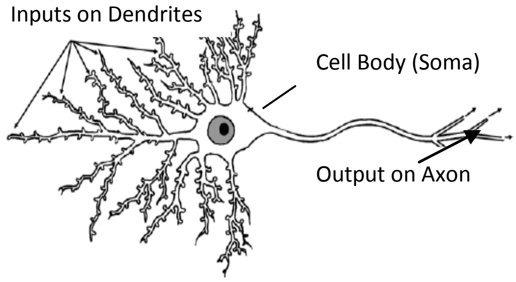

Fig.1 Structure of a neuron

3. Model of an Artificial Neuron

Artificial neural network motivated from biological analogy. The human brain is a highly complex structure. It is viewed as a massive, highly interconnected network of simple processing elements called neurons. The behavior of a neuron can be captured by a simple model as shown in figure 2.Every component of the model has a direct analogy to the actual component of a biological neuron and hence it is termed as artificial neuron.

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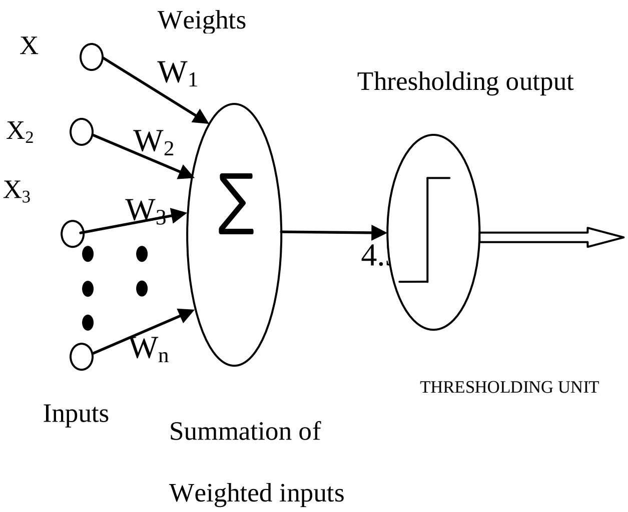

Fig.2.Electrical Model of an Artificial Neuron

X_1, X_2, X_3,…., X_n are the n inputs to the artificial neurons. W_1, W_2, W_3,….,W_n are the weights attached to the input links i.e strength of connection. As a biological neuron receives all inputs through the dendrites, sums them and produces an output if the sum is greater than a threshold value. The input signals are passed on to the cell body through the synapse which may accelerate an arriving signal.

This acceleration of the input signals that is modeled by the *weights.* Synapse which transmits a stronger signal will have a correspondingly larger weight while a weak synapse will have smaller weights. Weights are multiplicative factors of the inputs to account for the strength of the synapse. Hence, the total input I received by the soma of the artificial neuron is

$$\emptyset(I) = \begin{cases} 1, & I > 0 \\ 0, & I \leq 0 \end{cases} \quad 4.4$$

$$I = w_1x_1 + w_2x_2 + w_3x_3 + \ldots + w_nx_n$$

$$= \sum_{i=0}^{n} \text{wixi} \quad 4.1$$

To generate the final output y, sum is passed to a non-linear filter ∅ called *Activation function*, or *Transfer function, or Squash function* which releases the output.

$$y = \emptyset(I) \quad 4.2$$

$$y = \emptyset\left(\sum_{i=0}^{n} \text{wixi} - \theta\right)$$

A very commonly used Activation function is the *Thresholding function*. In this, the sum is compared with a threshold value θ. If the value of I is greater than θ, then the output is 1 else it is 0.

$$\emptyset(I) = \begin{cases} +1, & I > \theta \\ -1, & I \leq \theta \end{cases} \quad 4.5$$

Where, ∅ is step function known as Heaviside function and such that

Figure.3 illustrates the thresholding function. This is convenient in the sense that the output signal is either 1 or 0 resulting in neuron being on or off.

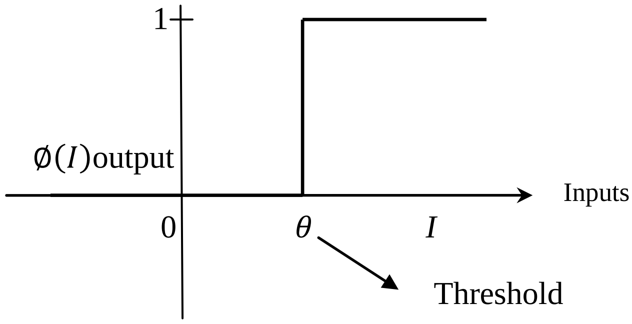

Fig.3 Thresholding function

Other than Thresholding function other choices for Activation function as follows.

4.1 Signum function

It is known as the Quantizer function, the function ∅ is defined as

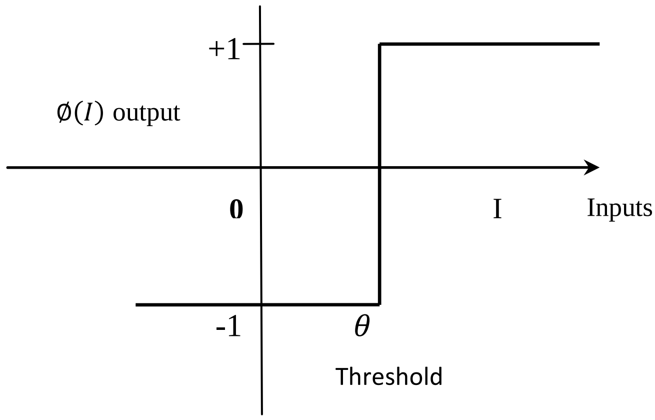

Fig. 4.2 Signum function

4.2 Sigmoidal function

That varies gradually between the asymptotic values 0 & 1 or -1 and +1 and is given by

$$\phi(I) = \frac{1}{1+e^{-\alpha I}} \qquad 4.6$$

where α is slope parameter, which adjusts the abruptness of the function as it changes between the two asymptotic values. Sigmoidal functions are differentiable, which is an important feature of neural network theory. Fig. 4 illustrates the sigmoidal function.

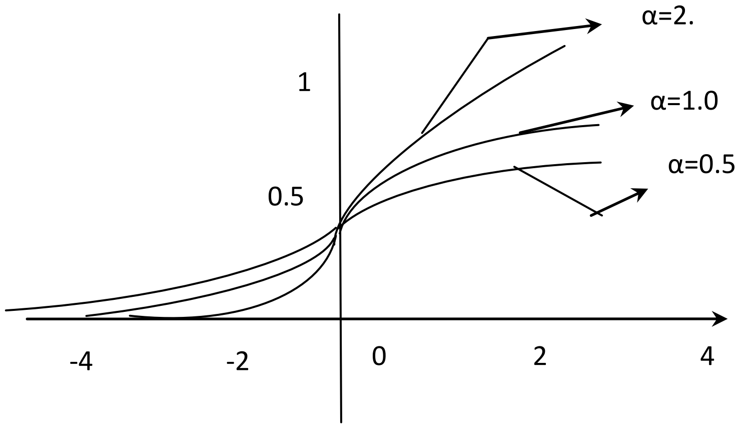

Fig. 4. Sigmoidal function

4.3. Hyperbolic tangent function

The function is given by

$$\phi(I) = \tanh(I) \qquad 4.7$$

It can produce negative output values.

4. Neural Network Architectures

An artificial neural network is defined as a data processing system consisting of a large number of simple highly interconnected processing elements .An ANN structure can be represented using a *directed graph*. Directed graph assume significance in Neural Network theory since signals in NN systems are restricted to flow in specific directions. A graph G is an ordered 2-tuple(V,E) consisting of a set V of *vertices* and a set E of *edges*. The vertices of the graph may represent neurons and the edges, the synaptic links. The weights attached to the synaptic links.

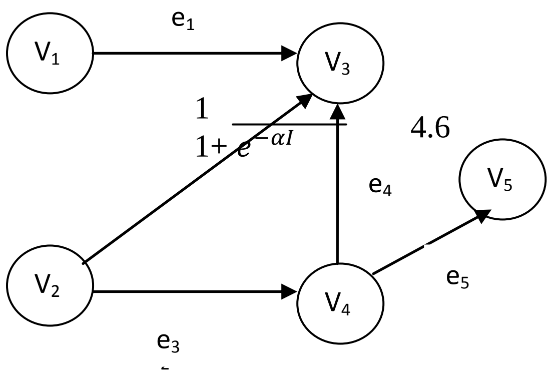

Fig.5 An example of digraph

Vertices V = {V_1, V_2, V_3, V_4, V_5}

Edges E = {e_1, e2, e3, e4, e5}

5.1.Single Layer Feedforward Network

This type of network comprises of two layers, as the *input payer* and the *output layer*. The input layer neurons receive the input signals. The *output layer* neurons receive the output signals. The synaptic links carrying the weights connect every input neuron to the output neuron but not vice-versa. This is feedforward in type or acyclic in nature. The network is called as single layer even though two layers are there since output layer alone only performs computation. The input layer transmits the signals to the output layer. Figure 6 illustrates an example of network.

X_i: input neurons

Y_j: Output neurons

W_{ij}: Weights

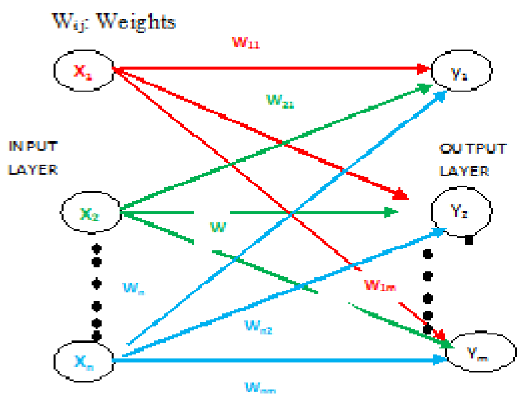

Fig.6. Single layer feedforward network

5.2.Multilayer Feedforward Network

This network made up of multiple layers. In this network class besides from an input and an output layer one or more intermediate layers are there. These intermediate layers are called *hidden layers*. Before directing input from input layer to output layer hidden layer performs useful intermediary computations. The computational units of the hidden layer are called as *hidden neurons* or *hidden units*. The input layer neurons are connected to hidden layer neurons. Weights on the link between input and hidden layers are called as *input –hidden layer weights*. Same way hidden layer neurons are connected to output layer neuron. The corresponding weights are referred as hidden-output layer weights. Fig.7 illustrates the multilayer feedforward networks with *l* input neurons, m_1 neurons in first hidden layer, m_2 in second and so on. *n* neurons in output layer.

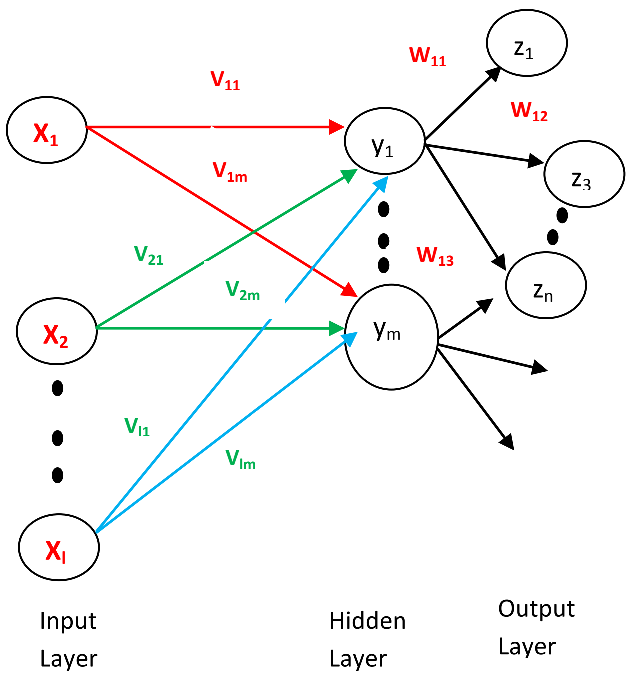

Fig.7 A multilayer feedforward network

X_i: Input Neurons

Y_j: Hidden Neurons

Z_k: Output Neurons

V_{ij}: Input hidden layer weights

W_{jk}: Output hidden layer weights

5.3.Recurrent Networks

These networks differ from feedforward network architectures. i.e. there is at least one feedback loop. In these network there is one layer exists with feedback connections as shown in fig. 8. Also there could be neurons with self-feedback links.

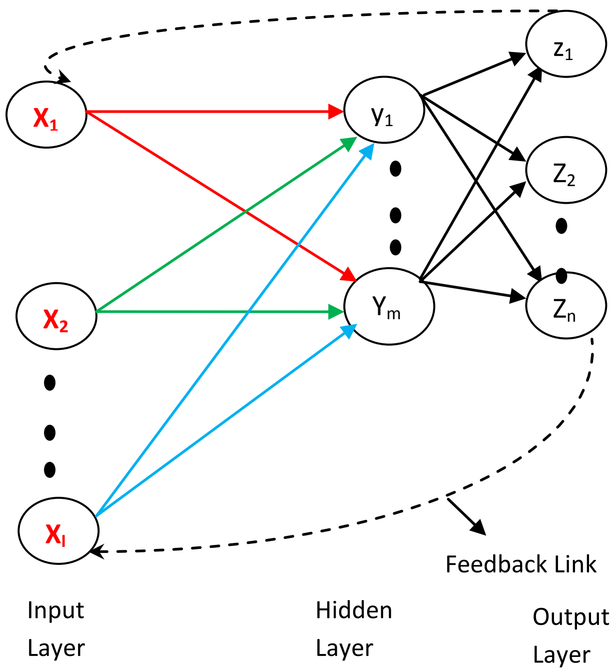

Fig.8 Recurrent neural network

6. Properties and capabilities of NN

Nonlinearity. A neural network, made up of an interconnection of nonlinear neurons, is itself nonlinear. Nonlinearity is a highly important property, particularly if the underlying physical mechanism responsible for generation of the input signal is inherently nonlinear.

Input-Output Mapping. The network learns from the examples by constructing an input-output mapping for the problem at hand. Such an approach brings to mind the study of nonparametric statistical inference.

Adaptivity. Neural networks have a built-in capability to adapt their synaptic weights to changes in the surrounding environment.

Evidential Response. In the context of pattern classification, a neural network can
be designed to provide information not only about which particular pattern to select, but also about the confidence in the decision made.

Contextual Information. Every neuron n the network is potentially affected by the global activity of all other neurons in the network.

Fault Tolerance. Its performance degrades gracefully under adverse operating conditions.

VLSI Implementability.

Uniformity of Analysis and Design.

Neurobiological Analogy.

7. Application Domains for NN

a. Pattern recognition

Neural networks have shown remarkable progress in the recognition of visual images, handwritten characters, printed characters, speech etc.

b. Constraint Satisfaction

Comprises problems which need to satisfy constraints and obtain optimal solutions. Eg. Finding shortest path tour between the given set of cities.

c. Forecasting and risk assessment

Since neural networks can examine a lot of information quickly and sort it all out, it can be used to predict stock prices, banking. It can predict it from last trend.

Conclusion

The literature review above shows neural network models have many attracting properties. It gives basic concepts of neural networks. The working and comparison between the biological neuron and artificial neurons. It discussed about the different model of artificial neuron. Also what are the different architectures of neural networks. Finally the different application domain of the neural networks. Also studied Properties and capabilities of NN.

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