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Review Article

A Review: Artificial Neural Network

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Abstract

Neural networks are those information processing systems, which are built and performed to design the human brain. The main objective of the neural network research is to evolve a computational device for representing the brain to perform various evaluating tasks at a faster rate than the traditional systems. Neural networks are latest method of programming computers. Several programs that utilize neural nets are also proficient Neural networks have appeared in the past few years as an area of different opportunity for research area, development and application to a variety of real world problems because of their rapid feedback and parallel architecture. Artificial neural networks perform various tasks such as pattern-matching and classification, optimization function and data clustering. These tasks are very difficult for traditional for implementation of artificial neural networks, high-speed digital computers are used, which makes the simulation if neural processes feasible. This paper provides a broad overview of the wide array of artificial neural networks, some of the most commonly network architecture and various learning processes currently in use in research. Also concisely describes several applications of it.

Keywords: *Biological neuron, artificial neuron, Neural network architecture, Activation function, Learning process, Hebbian rule, Back-propagation algorithm.*

1. Introduction

Artificial neural network is basically inspired by biological neural networks that are massively parallel computing systems consisting of an intensively large number of simple processing elements with many interconnections called as nodes or neurons, which are configured in regular architecture. Each neuron is used to be connected with other one by a strong connection link. Each connection link is integrated with particular weights which hold information about the input signal (like synapses). This kind of information is used by the neural net or nodes to solve a particular problem. These weights are corresponding to each connection link, computed by a mathematical function which leads to the activation of neuron as internal state of its own. Some another functions (like identity, binary step, bipolar step, sigmoidal function) may be used to evaluate the output of the artificial neuron (sometimes in corresponds of a certain threshold). The activation function applied to neurons in this network just sum their inputs.

Artificial neural network is like people that learn by examples that make them very flexible and powerful. Since the basic of artificial neural network is to manage as well as process the information, they are widely used in various engineering purposes such as pattern recognition, fraud-detection, medical diagnosis, and data classification through the concept of learning process. Learning process in biological systems includes adjustments to the synaptic connections links that exist between the neurons.

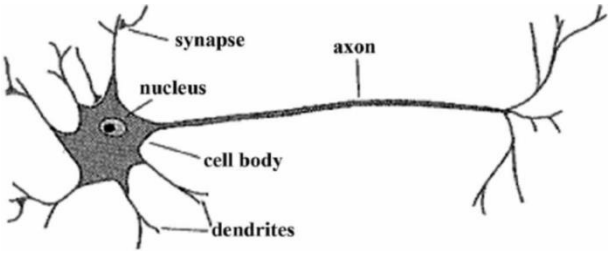

Figure 1: Biological Neuron

In the human brain, a normal neuron accumulates signals from others through a host of fine structures called *dendrites*.

The neuron sends out projections of electrical activity through a long, thin stand known as an *axon*, which splits into thousands of branches.

At the end of each branch, a structure called a *synapse* converts the activity from the axon into electrical effects that inhibit or excite activity in the connected neurons.

$$x = \sum_{i=1}^{N} AiWi + \Theta$$

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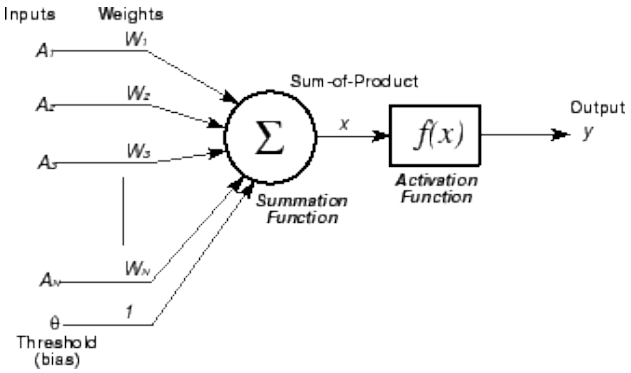

Figure 2: Artificial Neuron

In the artificial neuron, input neurons have only one particular input of each, then weights are assigned to be multiplied with the particular inputs and further activation function (as processing element) is applied to get summation of these inputs from neurons for obtaining the output of neuron.

There are a wide variety of ANNs that are used to derive the meaning from complicated or imprecise data could be used to extract patterns and detect trends that are too difficult to be noticed by either humans or other computer techniques. A trained neural network can be considered as an expert system in the classification of different information that has been analysed accordingly. An expert system consists of set of programs that operate encoded knowledge to solve given problems in a restricted discipline which normally requires human skills and answer what if questions.

Other several advantages include:

- Adaptive learning: An artificial neural network has an ability to learn how to do tasks based on the data given for training or initial experience.
- Self-Organisation: An ANN can design its own organisation or representation of the information that it accepts during learning process.
- Real Time Operation: ANN computational procedure may be carried out in parallel architecture, and special hardware devices are being designed and manufactured in order to evaluate the real world problems.
- Fault Tolerance via Redundant Information Coding: Partial shattering of a network give rise to the corresponding reduction of performance. However, some networks have ability to be retained even with major damage.

Neural network allow using distinct approach in order to solve the problems than that of conventional computers. Conventional computers use an algorithmic technique i.e. the computer obeys a set of instructions for solving the problems. They restrict the problem solving capability that we already understand and analyse how to solve a particular problem. Conventional computers would be more useful in order to achieve solution that we don't exactly know how to solve it. Neural networks manage information in a same way as the human brain does. This network is comprised of a large number of extremely interconnected neurons (processing elements) that operate in parallel mode to solve a specific problem.

Neural network work on the examples, they cannot be arranged to perform a specific task. The examples must be chosen carefully otherwise effective time is wasted or even the network might be operating incorrectly. The main disadvantage is that the network discovered how to solve the problem by their own, their operation can be uncertain. On the other hand, conventional computers use experimental method in which problem is to solved must be known and bounded in small explicit instructions. These instructions are transformed to a high level language code and then converted into machine language code that the computer can understand. These machines are totally certain or predictable. There are tasks are more suited to arithmetic operations as well as to neural networks. Even for large number of tasks, require systems that use a combination of the two methods (normally a conventional computer is used to handle the neural network).

The rest of the paper is organized as follows: Section 2 emphasize the introduction of neural network architecture (single-layer feed-forward and multilayer feed-forward network architecture), Section 3 defines the different activation function used in the neural network paradigm, Section 4 determines the various learning process through which achieve the output of network (supervised, unsupervised, reinforcement learning) and section 5 involves the several applications of artificial neural network and Conclusion are given in last section

2. Neural network architecture

The arrangement of neurons to form layers and the connection link formed within and in between layers is called the neural network architecture. The arrangements of these processing elements and geometry of their interconnections are essential for an ANN. The point where the connection originates and terminates should be noted, and the function of each processing element in an ANN should be specified.

A. Single-layer feed-forward network

It is defined as a layer is formed by taking a processing element and combining it with other processing elements. Practically, a layer implies the input stage and the output stage are linked together with each other.

These linked interconnections lead to the formation of various network architectures. When a layer of the processing node is formed, the inputs can be connected to these elements with various assigned weights, resulting in a series of outputs, one per node. Thus, a single-layer feed-forward network is formed.

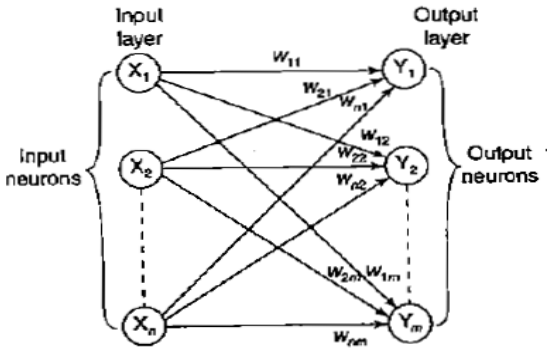

Figure 3: Single-layer feed-forward network

B. Multilayer feed-forward network

A multilayer feed-forward network is formed by the correlations of several layers. There are basically three layers of artificial neural network as input layer, hidden layer, and output layer.

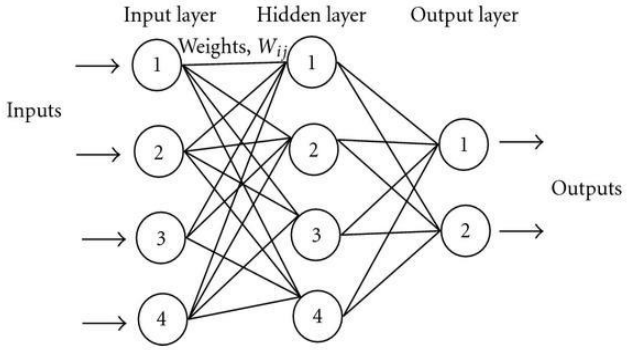

Figure 4: Multilayer feed-forward network

The input layer receives the input and this layer has no function except buffering the input signal. The output layer generates the output of the network. Another layer is formed between the input and output layers is called hidden layer. The hidden layer is internal to the network (no direct contact with external environment). Each hidden unit's activity is controlled by the activities of the input units and the weights assigned on the connections links between the input and the hidden units. More the number of the hidden layers more are the complexity of the network.

1) Activation function

The main role of activation function is to evaluate the exact output of an ANN. The information processing of the neurons can be considered as made up of two vital parts: input and output. An integration function (say f) is related with the input of a processing element (neuron). This function performs to combine information or activation from an external source or other different processing elements into a net input to a processing element. The non-linear activation function refers to ensure that the response of particular neuron is bounded such as actual output of neuron is conditioned as a result of activating stimuli and can be controllable.

There are various activation functions as follows:

- *Identity function:* It is kind of linear function and defined as :

f(x) = x for all x. Here the output remains same as the input. The input layer basically uses the identity activation function.

- *Binary step function:* This function can be defined as :

$$f(x) = \begin{cases} 1 & \text{if } x >= \Theta \\ 0 & \text{if } x < \Theta \end{cases}$$

where Θ represents the threshold value. This activation function is widely used in single layer network to convert the input to output in binary form (1 or 0).

- *Bipolar step function*: This function can be defined as :

$$F(x) = \begin{cases} 1 & \text{if } x >= \Theta \\ -1 & \text{if } x < \Theta \end{cases}$$

Where, Θ represents the threshold value. This activation function is widely used in single layer network to convert the input to output in bipolar form (+1 or -1).

- *Sigmoidal function*:

The sigmoidal function are widely used in back-propagation networks due to considering the relationship between the function's value at a point and derivative's value at that point which reduces the burden of computational during learning.

  - ❖ *Binary sigmoid function*: It is also referred as logistic or unipolar sigmoid function. It can be defined as:

$$sig(x) = \frac{1}{1 + e^{-\beta x}}$$

Where, β is the steepness parameter, the range of sigmoid function from 0 to 1.

  - ❖ Bipolar sigmoid function: It is defined as :

$$sig(x) = \frac{1}{1 + e^{-\beta x}}$$

Where, β is the steepness parameter, the range of sigmoid function from -1 to +1.

- *Ramp function:* the ramp function is defined as :

$$F(x) = \begin{cases} 1 & \text{if } x>1 \\ x & \text{if } 0<=x<=1 \\ 0 & \text{if } x<0 \end{cases}$$

2) Learning process

A learning process in the ANN can be described as the procedure for updating network architecture and connection weights so that a network can efficiently perform a specific task. The network usually must retain the connection weights from unused training patterns. Performance of the network is being enhanced by updating the assigned weights iteratively over the time. There are generally three categories that can be classified in the learning process of artificial neural network as: Supervised learning, unsupervised learning, and reinforcement learning.

A. Supervised Learning

ANNs follow supervised learning in such a way that each input vector requires a corresponding target vector, which represents the desired output. The input vector compared with the target vector represents training pair.

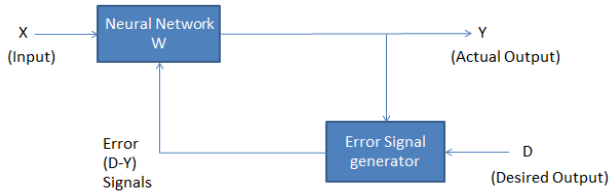

Figure 5: Supervised Learning

During training, the input vector is granted to the network, which gives the output vector (actual output). Then the actual output is compared with the desired (target) output vector. If there is a difference between these two vectors, then an error signal is generated by the network. This error signal is used for adjustments of weights until the actual output matches the desired (target) output. In this type of learning process or training, a kind of supervisor or teacher is needed for error minimization. In supervised learning, it is supposed that correct target output values are predefined for each input node. The ideal of supervised learning include error-correction learning, reinforcement learning and stochastic learning.

B. Unsupervised Learning

This type of learning process is self-determining and is not supervised by a teacher. In ANNs, input vector of homogeneous type are grouped without requirement of training data to identify how a component of each group looks or belongs to which category.

Figure 6: Unsupervised Learning

In this training procedure, the network accepts the input patterns and classifies these patterns to form clusters. When a new input pattern is implemented, the neural network gives an output response specifying the class to which the input pattern belongs. If the pattern class cannot be found then a new class is generated.

It is obvious that there is no feedback from the environment to determine whether the outputs are correct or not. In this criterion, the network must determine patterns, features, or categories itself from the input data and obtain relations over the output. This process is known as *self-organizing* in which clusters will be made by discovering similarities and dissimilarities among the objects.[4] The prototypes of unsupervised learning are Hebbian and competitive learning rule.

C. Reinforcement Learning

This learning process is resembles to supervised learning (in the case in which the correct target output values are known for each input patterns). There is available only interpreted information rather than exact information. The learning is based on this interpreted information is basically called as reinforcement learning and the feedback sent is called as reinforcement signal.
The reinforcement learning is category of supervised learning in which the trained network received some kind of feedback from its environment.

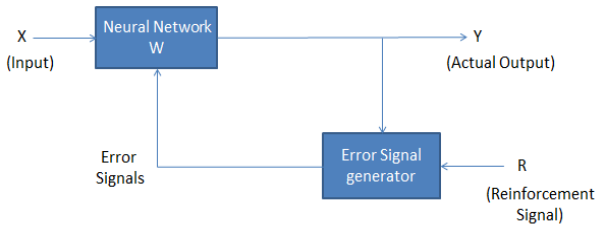

Figure 7: Reinforcement Learning

The external reinforcement signals are processed in the error signal generator, and the obtained interpreted signals are delivered to the ANN for adjustments of weights in order to get better feedback in future.

Hebbian Learning rule

Donald Hebb declared in 1949 that the learning is performed by the modification in synaptic gap in the human brain. According to the Hebbian learning rule, the weight vector is originated to increase proportionately to the product of the input and the learning signal. Here the learning signal corresponds to the neuron's output. Hebb demonstrated it as when an axon of cell A is close enough to excite cell B, and iteratively takes place in firing it, some growth process or metabolic change takes place in one or both the cells such that A's efficiency, as one of the cells firing , B is increased.

In Hebb Learning, if two interrelated neurons are 'on' concurrently then the weights assigned to processing elements can be increased by changing occur in their synaptic gap (strength) as follows :

w_i (new)= w_i (old)+x_io

Where, o is desired output for i= 1 to n (inputs).

Training flowchart for Hebb network

This flowchart describes the basic procedure of learning how to update the weights and biases for every training and target sample in the network.

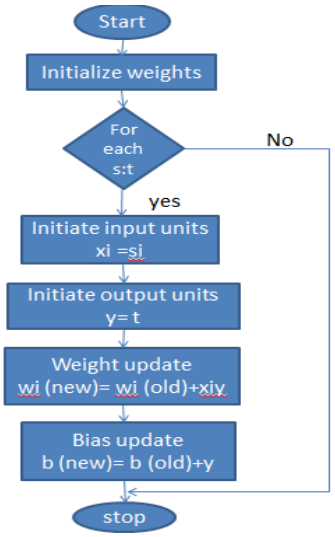

Figure 8: Flowchart of Hebb learning algorithm

Training Algorithm

Step 1: Firstly, initialize the weights as w_i *=0 for i=1 to n* (where n is total number of input neurons).
Step 2: Steps to be followed for each input training vector (s) and target output pair (t) as *s:t* (if occurred), otherwise stop.
Step 3: Activate the input vector through activation function (identity function) : x_i *=*s_i *for i=1 to n.*
Step 4: Next, Activate the output units as *y=t.*
Step 5: Updating the weights as well as bias takes place as:
w_i *(new)=* w_i *(old)+*x_i*y*
b (new)= b (old)+y

Back-propagation Algorithm

This learning algorithm is involved to multilayer feed-forward networks consisting of neurons (processing elements) with continual distinguishable activation functions. The network related with back-propagation learning algorithm are also called Back-propagation network (BPNs). For considering a set of input-output training pair, this algorithm gives a method for adjustment of weights in a BPN to categorize the given input samples correctly. This is a procedure in which error is propagated back to the hidden layer. This method is quite different from others because weights are evaluated during the learning process of the network.

The learning process of back-propagation network is done in three stages as – the feed-forward of the input training samples, the computation and back-propagation of the error, and adjustment of weights. Only computation of feed-forward phase is carried out to be tested in the back-propagation network. When the hidden layers are increased then the network training can be more complex. To update the weights, the error must be evaluated. The error corresponds to the difference between the actual (calculated) and desired (target) output that is easily measured at the output layer. It must be considered at the hidden layer, there is no direct guidance of the error.

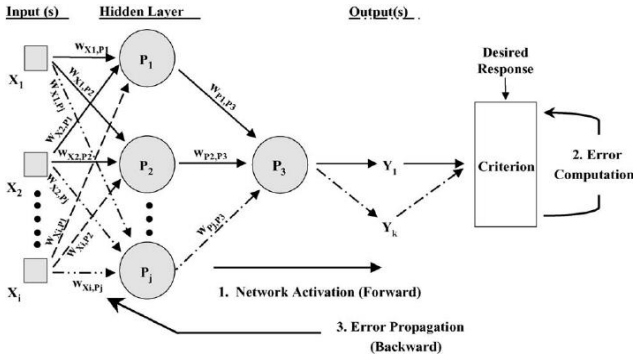

Figure 9: Back-propagation Network

Architecture

A back-propagation neural network is a multilayer, feed-forward neural network composed of an input layer, a hidden layer, and an output layer. The processing elements (neurons) present in the hidden and output layers have biases (connection links from units have activation is always 1). Bias is basically referred as weights. The architecture depicts the direction of information flow for the feed-forward phase and during the back-propagation phase of learning; signals are propagated in the reverse direction.

Algorithm

Neural network can be trained for purpose of classification or numeric predictions by using back-propagation algorithm.

Input:

- D, a data set composed of the training samples and their corresponding target values.
- L, the learning rate.
- Network, a multilayer feed-forward network.

Output:

- A trained neural network.

Method:

Step 1: Initialize all the weights and biases in the network; while terminating condition is not fulfilled.
Step 2: for each training input tuple X in D // propagate the inputs forward.
Step 3: for each input layer unit j where $Oj = Ij$; // output of an input unit is its actual input value.
Step 4: for each hidden or output layer unit j
$Ij = \sum_i WijOi + \Theta j$; //calculate the net input of unit j with respect to the previous layer, i
$Oj = \frac{1}{1+e^{-Ij}}$ // compute the output of each unit j.
Step 5: Back-propagate the error.
Step 6: for each unit j in the output layer
$Err_j = O_j(1-O_j)(T_j-O_j)$; //compute the error.
Step 7: for each unit j in the hidden layers, from the last to the first hidden layer
$Err_j = O_j(1-O_j)\sum_K ErrkW_{kj}$ // compute the error with respect to the next higher layer, k
Step 8: for each weight w_{ij} in network
$\Delta W_{ij}=(l)Err_jO_i$; // weight increment.
$W_{ij}= W_{ij}+\Delta W_{ij}$; // weight increment.
Step 9: for each bias θ_j in network
$\Delta\Theta_j= (l)Err_j$; // Bias increment
$\Theta_{ij}= \Theta_{ij}+\Delta\Theta_{ij}$; // Bias update

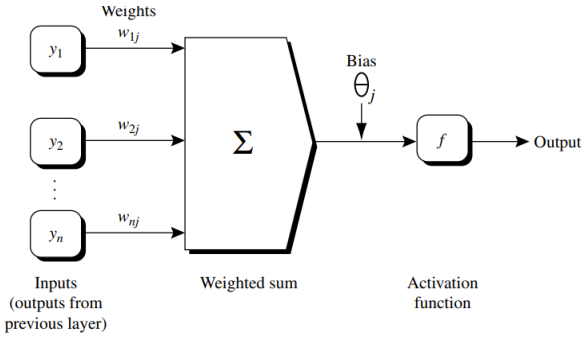

Figure10: Learning factors for back propagation network

Initialize the weights

The weights are initialized to the random numbers (e.g., ranging from −1.0 to 1.0). Each unit has a bias related with it. The biases are similarly initialized to small random numbers.

Propagate the inputs forward

First, the training sample is providing to the input layer of network. The inputs pass through the input units, unvaried. Next, the net input and output of each unit in the hidden and output layers are computed as a linear combination of its inputs. Each connection has a weight. To compute the net input to the unit, each input connected to the unit is multiplied by its corresponding weight, and then summed. The net input, I_j is

$Ij = \sum_i WijOi + \Theta j$;

Where w_{ij} is the weight assigned to the network, O_i is the output of unit i from the previous layer and θ_j is the bias of the unit.

Activation function is applied to the network (sigmoid or logistic function) used, so the output of unit j is computed as:

$Oj = \frac{1}{1+e^{-Ij}}$

Back-propagate the error

The error is back propagated by adjusting the weights and biases to indicate the error originating in the network.

3. Applications

Today, ANN operates a major continuation to computation the tasks. Different types of networks available for several applications. A rapid increment towards understanding of the ANNs leads to improved network paradigms and application opportunities as follows:

Neural network in medicine

Artificial Neural Networks (ANN) is currently a popular research area in medicines. The research is based on modelling the human body parts and recognising diseases from the various scan techniques (e.g. cardiograms, CAT scans, ultrasonic scans, etc.).

Neural network in business

Neural network would fit into business domain or financial analysis in order to achieve resource allocation and scheduling. Database mining implicit patterns can be searched out within the explicitly information storage databases (such as the Hopfield-Tank network for optimization and scheduling).

- Marketing: Such a marketing application like Airline Marketing Tactician (AMT) is a computer system composed of several intuitive technologies including expert systems. A neural network approach is federated with the AMT and trained by back-propagation to accommodate the control of airline seat allocations in marketing.[2] The system is configured to monitor and suggest booking advice for each departure. Such application can provide a technological advantage for users of the system.
- Weather Prediction: Inputs that include weather reports from the environmental areas. Outputs would be the future weather condition in particular areas based on the input samples. Effects included such as ocean currents and jet streams.

- Voice recognition: It could be acquired by determining the audio oscilloscope pattern like stock market graph
- Fraud detection: Fraud detection concerning insurances, taxes or credit cards could be self-operated using neural network analysis of previous occurrences.
- Staff scheduling: Requirements for retails stores, police stations, banks, restaurants, etc. could be estimated corresponding to customer paydays, holidays, weather, season, etc.
- Machinery control: It could be self-regulatory technique by recording the actions of experienced machine operators into neural network.
- Data mining, cleaning and validation: It could be achieved by evaluating records suspiciously different from the pattern of their peers.
- Employee hiring: It could be enhanced if the neural networks were able to determine which job applicants would show the best job performance.

Conclusion

The extraordinary information processing proficiencies of artificial neural network and their ability to learn from examples make them systematic problem-solving technique. This paper discusses artificial neural networks by determining the concept of biological neurons and artificial neurons. In biological neural networks, learning takes place by updating the performance of the synapses in order to influence of one neuron on another changes. In artificial neural network, there are interconnected units or nodes known as artificial neurons (processing elements). Each connection link between these processing units/elements can convey a signal from one to another. The artificial neuron that receives the signal can process it accordingly. The artificial neuron has two approaches of operation: the training mode and the using mode. In the training mode, the neuron can be trained/learnt to fire (or not) only for particular input patterns. In the using mode, when a taught input pattern is discovered at the input, its associated output becomes the current output.

This paper also discusses the behavior of learning processes (such as supervised , unsupervised , and reinforcement learning) in order to update the network architecture and weights assigned to a particular connection between processing elements for achieving better efficiency to do specific task.

The enlarged development of ANNs is associates to various features they possess as (i) the capability to identify and learn the latent between input and output without explicit consideration, whatever the problem's dimensionality and system irregularity, and (ii) the high tolerance towards noise and measurement errors due to distributed processing within the network. Neural network also contribute to other research areas such as: neurology and psychology. They are regularly used to model parts of living organisms and to investigate internal mechanisms of human brain as well.

It is highly recommended that different hybrid system (Neuro fuzzy hybrid systems, Neuro genetic hybrid systems) can be used to manage imprecise information, resolve conflicts by collaboration and aggregation also mimic the human decision-making procedure. They are able to make computation fast by using fuzzy techniques. To optimize the ANNs for forecasting and classification problems, Genetic algorithm can be used to search for correct fusion of input data, optimal network interconnection patterns as well as control the parameters (learning rate, tolerance level, etc.) based on the training data sets.

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