Volume 5, Issue 10, October-2015 ISSN: 2277 128X
International Journal of Advanced Research in Computer Science and Software Engineering
Research Paper
Available online at: www.ijarcsse.com

An Effective Weather Forecasting using Levenberg-Marquardt Method

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Abstract— The Weather forecasting is the application of science and technology to predict the state of the atmosphere for a given location. ANN provides a method for solving nonlinear problems that are difficult to be solved by traditional techniques. In this paper neural network model training of the network is performed using the Back-propagation algorithm that uses supervised learning. The proposed network is trained and tested with actual data of the years April 2012 to March 2015 of New Delhi which comes from meteorological department. The weather parameters like temperature, dew point, humidity, sea level pressure, visibility and wind speed has been collected. Artificial Neural Network is used to predict future weather condition based upon above parameters. ANN is used with Levenberg Marquardt Algorithm, Gradient Descent and Gradient Descent with Momentum and comparison are done between them.

Keywords— Back-propagation Network, ANN, Levenberg-Marquardt Algorithm, GDM and GD.

I. INTRODUCTION

Forecasting the weather is essential to help you prepare for the best and the worst of our climate. Weather condition is state of atmosphere at given time in terms of weather variables like temperature, pressure, wind speed etc. Accurate weather predictions are important for planning our day-to-day activities. Farmers need information to help them plan for the planting and harvesting of their crops. Airlines need to know about local weather conditions in order to schedule flights. Numerical models are not able to produce suitable results in local and short-term cases. Statistical methods are of vast value in long-range weather forecasts. Statistical method has drawbacks that there is no ultimate end in finding the best predictors and it is not useful to study the highly non-linear relationship between weather parameter and its predictors. After that ANN came into existence in 1986 which is able to remove these two drawbacks of research workers. It can handle the complex non-linear problems better than numerical and statistical methods. Present weather forecasting involves a combination of computer models, observation, and knowledge of trends and patterns. Most of the computer models used for predictions is run by the National Weather Service. For better weather forecasting some advantages of neural network are:

1. The NN has the ability to represent both linear and non linear relationship directly from the data being modelled.
2. The NNs is a structure that can be adjusted to produce a mapping or relationship among the data.
3. NN is able to capture and represent complex input/output relationships.
4. The neural networks learn by examples.
5. The NNs possess the capability to provide good generalization.
6. They can predict new outcomes from past trends.
7. The NNs are robust systems and are fault tolerant.
8. The NNs can process information in parallel, at high speed, and in a distributed manner.

II. THE NEURAL NETWORK MODEL

A neural network is a powerful data modelling tool that is able to represent complex input/output relationships. It is a simplified model of the biological neuron system which is made up of highly interconnected neural computing elements. Neural Network is mostly used to solve many practical tasks such as regression problems. Neural networks resemble the human brain in the following two ways:

1. A neural network acquires knowledge through learning process.
2. A neural network's knowledge is stored within interneuron connection strengths known as synaptic weights.

Traditional linear models are simply insufficient when it comes to modelling data that contains nonlinear characteristics. An artificial neuron is a unit that performs a simple mathematical operation on its inputs and imitates the functions of biological neurons and their unique process of learning. The neural unit processes the input information into the output information. Each of these units is a simplified model of a neuron and transforms its input information into a neuronal output response. This transformation involves the activation of the neuron as computed by the weighted sum of its inputs.

This activation is then transformed into a response by using a transfer function. It consists of a neuron with a single input vector $P_1, P_2, P_3 \ldots\ldots\ldots\ldots, P_R$. These inputs are multiplied by weights $w_{1,1}, w_{1,2}, w_{1,3}, \ldots\ldots\ldots\ldots\ldots w_{1,R}$ are represented in (fig. 1). The weighted inputs are fed to the summing junction. The output is

$$n = w.P + b \quad (1.1)$$

$w.P$ is the dot product of single row matrix w and vector P.

R = number of elements in input vector.

The sum of the weighted inputs and the bias forms the input to the transfer function f. Neurons can use any differentiable transfer function f to generate their output. Transfer function or Activation function with a bounded range are often called squashing function. The function $logsig$ generates outputs between 0 and 1 as the neuron's net input goes from negative to positive infinity. This function is easy to differentiate and can reduce the computation burden for training. This makes it more advantageous for used in back-propagation. It is given as:

$$a = logsig(n) \quad (1.2)$$

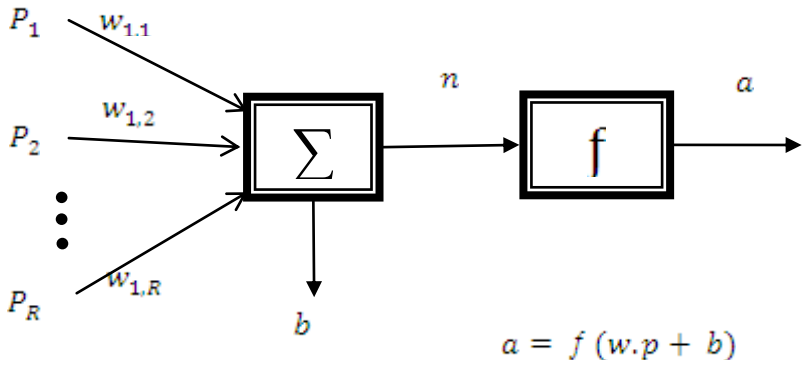

Fig 1 The Neural Network Model

III. ARTIFICIAL NEURAL NETWORK

All A neural network is simply a class of mathematical algorithms which has graphic notation for a large class of algorithms and produce solutions to a number of specific problems. ANN just like people learns by example. An Artificial Neural Network (ANN) is an information processing system that is inspired by biological nervous systems, which process information. It consist of a huge number of highly interconnected processing elements (neurons) working in unity to solve specific problems. An ANN is mostly used for a particular application, such as pattern recognition or data classification, through a learning process. The ANN contains a large number of simple neuron-like processing elements and a large number of weighted connections between the elements. It consists of three layers: input layer, hidden layer and output layer. The Input layers receive input signals or data from the external world and encode the data or signal pattern. The Hidden layer can consist of one or more layers of neurons with the following layers receiving input from preceding layers in feed-forward architecture. The Output layer is the final layer of the network. The neurons present in this layer present the output of the network. Each individual neuron works in parallel to find a solution.

Here $x_1, x_2, x_3 \ldots x_n$ are the n inputs to the artificial neuron and $w_1, w_2, w_3 \ldots w_n$ are the weight attached to the input links as shown in (fig. 2). The total input I received by the sum of the artificial neuron is

$$I = w_1x_1 + w_2x_2 + \ldots\ldots + w_nx_n \quad (1.3)$$

$$I = \sum_{i=1}^{n} w_i x_i \quad (1.4)$$

The sum is passed on to a non-linear filter Ø called Activation function, or Transfer function, or Squash function which releases the output. The output y is given as

$$Y = \emptyset(I) \quad (1.5)$$

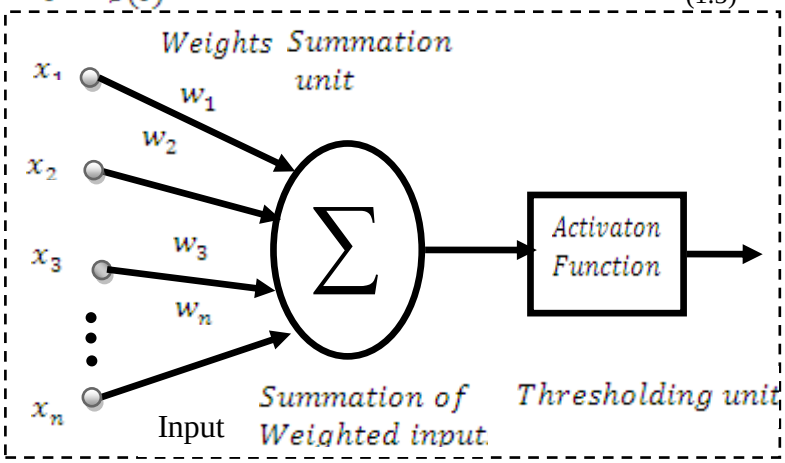

Fig 2 ANN Model

Neural networks are widely applied to systems such as:

1. Support for medical diagnosis
2. Financial market prediction
3. Voice and handwriting recognition
4. Flood prediction, and solar flare forecasting

IV. RELATED STUDY

The Chattopadhyay et al. in (2000) develop a predictive model for average summer monsoon rainfall amount over India. To develop the predictive model, Back-propagation method with Conjugate Gradient Descent algorithm has been implemented. The Neural Network with the Back-propagation method has been learned thrice to reach a good result. ANN with said algorithm is found to be skillful in predicting average summer monsoon rainfall amount over India.

Gavin et al. in (2015) studied the Levenberg-Marquardt method. LM is a standard technique used to solve nonlinear least squares problems. Nonlinear least squares methods involve an iterative improvement to parameter value in order to reduce the sum of the squares of the error between the function and the measured data point. Gavin used LM curve fitting method for. This LM curve fitting method is actually the combination of two minimization methods: Gradient Descent method and Gauss Newton method.

Gill et al. in (2010) analysed that Back Propagation algorithm using gradient descent method was the most important algorithm to train a neural network for weather forecasting but Back propagation algorithm suffers from several problems. To overcome some of these problems the combination of BP algorithm and genetic algorithm was used as compared to gradient based algorithm and stochastic optimizing algorithm. The proposed BP/GA technique can learn efficiently by combining the strengths of genetic algorithm with back propagation.

Kumar et al. (2012) presented ANN approach by developing effective and reliable non linear predictive models for weather analysis. He compares and evaluates the performance of the developed models using different Transfer Function, Hidden layers and Neurons to forecast maximum temperature for one year.

Nourani et al. (2012) revealed that the best model to estimate missing Rain-Gauge data is composed of feed forward network, which is trained by the LM method and considering only one hidden layer. It purposed an integrated ANN to investigate the hidden spatial relationship among the rain fall data of the stations as well as temporal auto-correlation. The results show the advantage of the proposed integrated model.

Shereef et al. (2011) proposed modified LM algorithm for neural network learning. The algorithm reduces the amount of oscillations in learning procedure. The results show that the proposed technique applied in better accuracy of prediction when compared with the conventional techniques of weather prediction.

Nawi et al. (2013) proposed a new algorithm which combines the best features of two algorithms one is LMBP and cuckoo search for improving convergence speed of ANN training. He used XOR and OR data sets for the training of CSLM algorithm. The proposed CSLM algorithm had better performance than other similar hybrid variants used.

Malik et al. (2014) stated that ANN is the best approach then traditional and numerical methods and back propagation is the most important algorithm to train a neural network for weather forecasting. This paper proposed a new technique of weather forecasting using Feed Forward ANN. This Paper revels that LM algorithm is the fastest method among other weather forecasting methods.

V. RESULTS AND OBSERVATIONS

The simulation is constructed for various parameters value such as average temperature, average dew point, average humidity, average sea level pressure, average visibility and average wind speed. The first five parameters represent the inputs while the sixth parameter average wind speed denotes the output data (target). The collected data is of last three years 2012 April to 2015 March. The total numbers of training samples are 1095. The network is trained by Levenberg-Marquardt method, gradient descent method and gradient descent method with Momentum. The work considers neural network with three layers i.e. input layer, hidden layer and output layer. Simulations are done by taking input p and network object net and then returning network output y. This work has used Function "mapstd" to normalize the inputs and target in order to give zero mean and unity standard deviation. The pn and tn are normalized values of inputs and output and ps and ts are the means and standard deviations of the original inputs and targets. The activation function for the hidden layer was "log-sigmoid" while that of the output layer was "pure-linear". During training the weights and biases of the network are iteratively adjusted to minimize the network performance function net.performFcn.

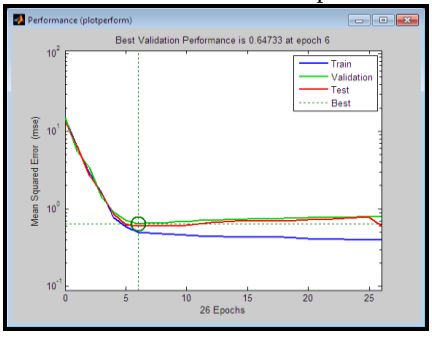

Fig 3 Performance Plot using Levenberg-Marquardt

The default performance function for feed-forward networks is mean square error MSE (mean square error) which is the average squared error between the network outputs y and the target outputs t for Gradient Descent and Gradient Descent with Momentum and SSE (sum square error) for Levenberg-Marquardt. The (fig 3, 4, 5) shown below are performance plot using LM, GD and GDM method.

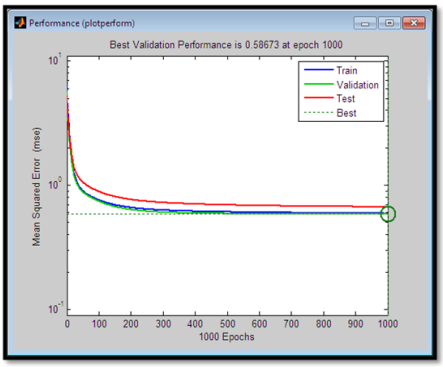

Fig 3 Performance Plot using Gradient Descent

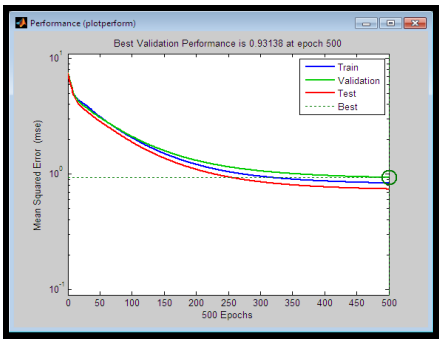

Fig 4 Performance Plot using Gradient Descent with Momentum

VI. CONCLUSION

The work propose a new technique of weather forecasting by using Feed-forward ANN. In this research data is trained by levenberg-marquardt algorithm and gradient descent algorithm and comparison between them. Levenberg-Marquardt is the fastest method than gradient descent method. As there are many BP algorithm but among them Levenberg BP has better learning rate. The Levenberg–Marquardt algorithm (LMA) is a very efficient training method for neural network. The LMA is a very popular curve-fitting algorithm used in many software applications for solving generic curve-fitting problems. Levenberg-Marquardt training normally used for small and medium size networks, if the enough memory available. Levenberg-Marquardt algorithm is faster and achieves better performance than the other algorithms in training. The gradient descent algorithm is generally very slow because it requires small learning rates for stable learning.

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