IJCSMS International Journal of Computer Science and Management Studies, Vol. 12, Issue 02, April 2012
ISSN (Online): 2231-5268
www.ijcsms.com

Analysis and Prediction of Temperature using Statistical Artificial Neural Network

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Abstract

This paper is about producing a prediction system by using artificial neural methods that will forecast temperature. This paper is based on three objectives. First, study of temperature and gathers all knowledge regarding the weather this is particularly studied in analysis part of the paper. Second, gather all knowledge about artificial neural network methods. Implement multilayer perceptron neural network with gradient descent(back propagation), BFGS, conjugate gradient training algorithm and will analyze the performance of all. Lastly, achieve an objective of developing a temperature prediction system. The general finding is that with BFGS algorithm, with multilayer perceptron model perform well with less prediction error and more accuracy than gradient descent and conjugate gradient, thus used for temperature prediction. To implement this project we make use of statistica software which provides the functionality called statistica artificial neural network(SANN) which is used here for temperature prediction and heavy weather software is used for data gathering.

Keywords: *Multilayer Perceptron Neural Network, Gradient Descent, BFGS, Conjugate Gradient, Statistica Artificial Neural Network, Statistica Software, Heavy Weather Software.*

1. Introduction

Temperature warnings are important forecasts because they are used to protect life and property. Temperature Prediction is the application of science and technology to predict the state of the temperature for a future time. Air temperatures prediction is of a concern in environment, industry and agriculture. The climate change phenomenon is as the first environmental problem in the world threatening the human beings. The industrial activities are so effective in this problem and cause the global warming which the world has been faced with, lately. Knowing the variability of ambient temperature is important in agriculture because extreme changes in air temperature may cause damage to plants and animals.

The concept of ANN is originated from the attempt to develop a mathematical model capable of recognizing complex patterns on the same line as biological neuron work. It is useful in the situations where underlying processes / relationships display chaotic properties. ANN does not require any prior knowledge of the system under consideration and are well suited to model dynamical systems on a real-time basis. It is, therefore, possible to set up systems so that they would adapt to the events which are observed and for this, it is useful in real time analyses, e.g., weather forecasting, different fields of predictions, etc. ANN provides a methodology for solving many types of non-linear problems that are difficult to solve by traditional techniques. Most meteorological processes often exhibit temporal and spatial variability, and are further plagued by issues of non-linearity of physical processes, conflicting spatial and temporal scale and uncertainty in parameter estimates. With ANN, there exists the capability to extract the relationship between the inputs and outputs of a process. Thus, these properties of ANN are well suited to the problem of temperature prediction under consideration [2]. The property of artificial neural networks that they not only analyze the data but also learn from it for future predictions makes them suitable for temperature prediction.

Neural networks provide a methodology for solving many types of non-linear problems that are difficult to be solved through traditional techniques. Furthermore neural networks are capable of extracting the relationship between inputs and outputs of a process without the physics being explicitly provided [8]. Hence these

characteristics of neural networks guided us to use them for the prediction of the weather processes.
The current research focused on developing ANN models with reduced average prediction error by increasing the number of distinct observations used in training. The approach applied here uses feed forward artificial neural networks (ANNs) with multi layer perceptron for supervised learning. The MLP is trained using three different algorithms; these include Gradient Descent, Conjugate Gradient and BFGS. The trained ANN was used to predict the future temperature conditions.

2. Methodology

2.1 The Multilayer Perceptron Neural Network

A schematic diagram of a fully connected MLP neural network [fig.1] with three inputs, four hidden units (neurons) and 3 outputs. Note that the hidden and output layers has a bias term. Bias is a neuron which emits a signals with strength 1.

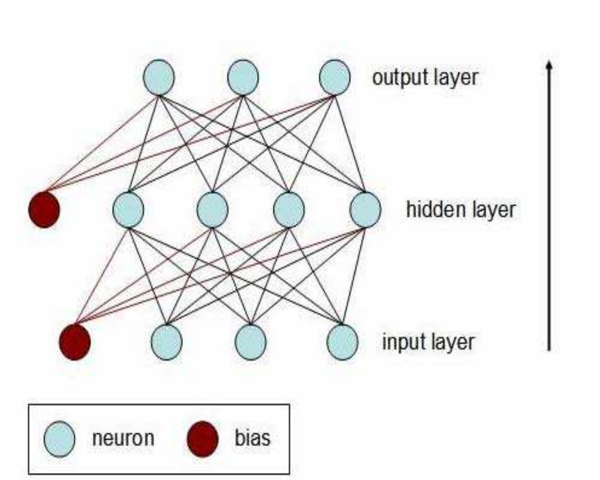

Fig. 1 Multilayer Perceptron Neural Network

Each neuron performs a weighted sum of their inputs and passes it through a transfer function *f* to produce their output. For each neural layer in an MLP network there is also a bias term[15]. A bias is a neuron which its activation function is permanently set to 1. Just like other neurons, a bias connects to the neurons in the layer above via a weight which is often called threshold. The neurons and biases are arranged in a layered feedforward topology. The network thus has a simple interpretation as a form of input-output model, with the weights and thresholds as the free adjustable parameters of the model. Such networks can model functions of almost arbitrary complexity, with the number of layers, and the number of units in each layer, determining the function complexity.

2.2 Statistica Software and Statistica Artificial Neural Network

Statistica provides comprehensive array of data analysis, data management, data visualization and data mining procedures. Its features include the wide selection of predictive modeling, clustering, classification and exploratory techniques made available in one software platform. Because of its open architecture, it is highly customizable and can be tailored to meet very specific and demanding analysis requirements. Statistica has a relatively easy to use graphical programming user interface, and provides tools for all common data mining tasks. It supports ANN (SANN) which is a very sophisticated modeling and prediction making technique capable of modeling extremely complex functions and data relationships.
Statistica products offer specialized tools for neural networks and other advanced analyses, as well as for determining sample sizes, designing experiments, creating real-time quality control charts, reporting via the Web, and much more . Statistica is a comprehensive, integrated data analyses, graphics, database management, and custom application development system featuring a wide selection of basic and advanced analytic procedures for business, data mining, science, and engineering applications. The software offers a very user-friendly interface, with flexible output management features, exceptional presentation-quality reporting, full OLE/ActiveX support, and set of Web enablement tools. It also includes data management optimized to handle large data sets, interactive database query tools, and a wide set of import/export facilities. It can handle datasets of unlimited size (, multiple input files, and multitasking. A broad selection of interactive visualization and graphics/drawing tools of the highest quality is fully integrated into the software, and each includes a complete set of automation options and a professional Visual Basic development environment. The statistica user interface offers unlimited customizability, flexibility, and automation options. This enables users to "modify their own Statistica," to work more efficiently by creating customized toolbars and menus containing frequently used macros, editing functions, formatting tools, or graph types. statistica can be customized to specifically suit your needs Statistica Neural Networks (SNN) unique and powerful Intelligent Problem Solver removes most of the problems usually associated with neural network design, automatically selecting suitable network types, complexity and input variables.

2.2 Training Multilayer Perceptron Neural Networks

Neural networks are highly nonlinear tools which are usually trained using iterative techniques. The most recommended techniques for training neural networks are

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the BFGS and Conjugate Gradient algorithm, which is used in this project of temperature prediction system. These methods perform significantly better than the more traditional algorithms such as Gradient Descent. These techniques may require a smaller number of iterations to train a neural network given their fast convergence rate and more intelligent search criterion.
Statistica Automatic Neural Networks providers several options for training MLP neural networks. These include BFGS, Scaled Conjugate and Gradient Descent. Once the number of layers, and number of units in each layer, has been selected, the network's weights and thresholds must be set so as to minimize the prediction error made by the network. This is the role of the training algorithms. The historical cases that you have gathered are used to automatically adjust the weights and thresholds in order to minimize this error. This process is equivalent to fitting the model represented by the network to the training data available. The error of a particular configuration of the network can be determined by running all the training cases through the network, comparing the actual output generated with the desired or target outputs. The differences are combined together by an error function to give the network error. The most common error functions are the sum squared error used here in temperature prediction project, where the individual errors of output units on each case are squared and summed together.

2.3 Back Propagation Algorithm

Back propagation is a systematic method of training multilayer artificial neural networks. It is built on sound mathematical base. The back propagation is a gradient descent method in which gradient of the error is calculated with respect to the weights for a given input by propagating the error backwards from output layer to hidden layer and further to input layer[20]. This method adjusts the weights according to the error function. So, the combination of weights which minimizes the error function is considered to be a solution of the problem [4].
The merits of back propagation algorithm are that the adjustment of weights is always toward the descending direction of the error function and that the adjustment only needs some local information. Secondly, the mathematical formula present here, can be applied to neural network with any architecture and does not require any special mention of the function to be learnt. Also the computing time is reduced if the weights chosen are small at the beginning [1]. Although back propagation algorithm is an efficient technique applied to classification problems, system modeling, adaptive robotics control, but it does have some pitfalls. For one, back propagation algorithm suffers from the scaling problem. It works well on simple training problems. However, as the problem complexity increases, the performance of back propagation falls off rapidly.

3. Implementation

This chapter will show implementation and result of a temperature prediction system. Here we implement all this multilayer perceptron neural network with gradient descent(back propagation), BFGS, conjugate gradient training algorithm and will analyze the performance of all and select the best among them for temperature prediction. Lastly, this project must achieve an objective of developing a temperature prediction system that can make a prediction temperature. The general finding is that BFGS algorithm, with multilayer perceptron model gives more accuracy than rest of the neural network.

3.1 Network Architecture

The figure shows 4-7-1 MLP Neural Network architecture, which consist of 4 input neurons each one for Dew point, Humidity, Pressure, Visibility respectively, 7 hidden neurons and 1 output neuron for output temperature (predicted temperature).This architecture is used here for predicting temperature in our project.

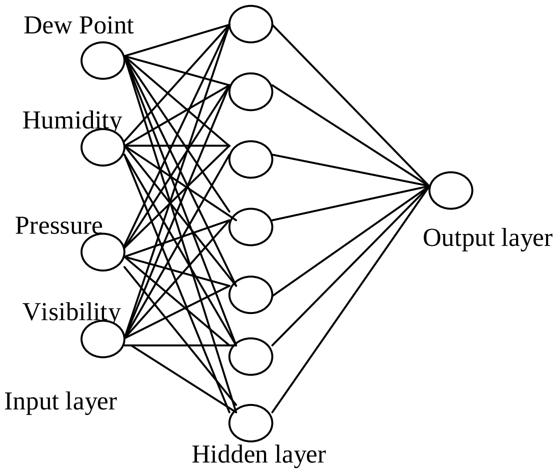

Fig.2 4-7-1 MLP Neural Network

Here ,in this fig you can see there are 4 neurons in input layer each for Dew Point, Humidity, Pressure and Visibility respectively. The one neuron in output layer which is for predicted temperature and there is only one hidden layer consisting of 7 neurons however, the no of neurons in hidden layer may vary depends on input dataset provided at the time of actual implementation of project.

Graph for Target vs Predicted Temperature

This is the output generated by neural network showing[Fig.3] target temperature and predicted output temperature for given input spreadsheet.

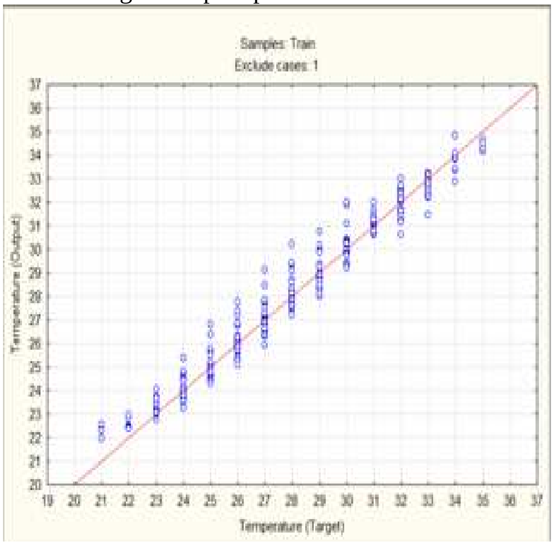

Fig.3 Training Performance

This the graph generated, showing the training performance of neural network useful for administrator for tracking performance of neural network[Fig. 4].

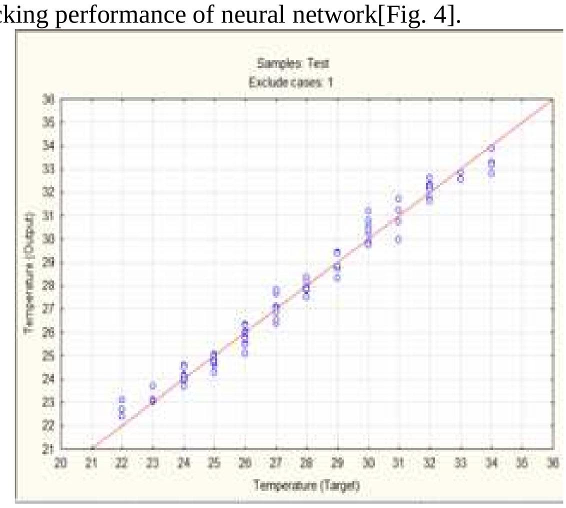

Fig.4Testing Performance

This graph[Fig. 5] , showing the testing performance of neural network .

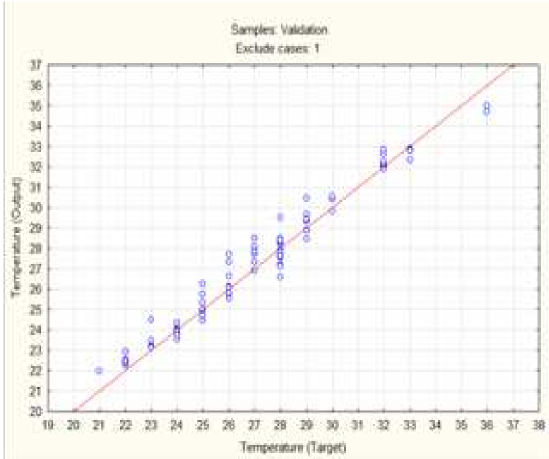

Fig5Validation

This graph , showing the validation of neural network

Summary of active networks (pronew)
Exclude cases: 1

Index	Net. name	Training perf.	Test perf.	Validation perf.	Training error	Test error	Validation error	Training algorithm	Error function	Hidden activation	Output activation
2	MLP 4-8-1	0.991168	0.994992	0.981045	0.000711	0.000580	0.002169	BFGS 37	SOS	Logistic	Tanh

Summary of Performance of Neural Network

Here, summary of the active neural network also be generated showing the network name, training performance (0.9911)of neural network, testing performance(.9949), validation performance(.9810), testing error(.00058), validation error(.002), training algorithm [BFGS] used to train neural network ,which error function is used, hidden and output activation function.

4. Result and Discussions

4.1Perfomance of Neural Network

The following figure 6 shows the performance of MLP with all the three training algorithms as you can see the performance of conjugate gradient algorithm is better than traditional gradient descent algorithm, and the performance of BFGS is much better than both algorithms.

Summary of active networks (pronew)
Exclude cases: 1

Index	Net. name	Training perf.	Test perf.	Validation perf.	Training error	Test error	Validation error	Training algorithm	Error function	Hidden activation	Output activation
1	MLP 4-7-1	0.972272	0.980188	0.980113	0.002671	0.002171	0.001999	Gradient descent 199	SOS	Logistic	Tanh

Summary of active networks (pronew)
Exclude cases: 1

Index	Net. name	Training perf.	Test perf.	Validation perf.	Training error	Test error	Validation error	Training algorithm	Error function	Hidden activation	Output activation
2	MLP 4-7-1	0.984502	0.992583	0.983475	0.001278	0.000717	0.001612	Conjugate gradient 41	SOS	Logistic	Tanh

Summary of active networks (pronew)
Exclude cases: 1

Index	Net. name	Training perf.	Test perf.	Validation perf.	Training error	Test error	Validation error	Training algorithm	Error function	Hidden activation	Output activation
2	MLP 4-8-1	0.991168	0.994992	0.981045	0.000711	0.000580	0.002169	BFGS 37	SOS	Logistic	Tanh

Fig.6 Performance of Neural Network

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4.2 Training Performance

As shown in figure 6 the training performance of Gradient Descent algorithm is .9722,where as conjugate descent has .9845 training performance and in case of BFGS it is .9911,so it is clearly seen that BFGS performs better than the both other algorithms.
The training error in case of gradient descent is more that is .002, in case of conjugate gradient ,it is .001 and in case of BFGS it is .0007 so here also the traditional gradient descent is low in performance and BFGS has least training error.

4.3 Testing Performance

As shown in figure 6 the testing performance of Gradient Descent algorithm is .9801,where as conjugate descent has .9925 testing performance and in case of BFGS it is .9949,so it is clearly seen that BFGS performs better than the both other algorithms.
The testing error in case of gradient descent is more that is .002,in case of conjugate gradient ,it is .0007 and in case of BFGS it is .0005 so here also gradient descent is low in performance and BFGS has least testing error.

4.4 Validation Performance

As shown in figure 6 the validation performance of Gradient Descent algorithm is .9801,where as conjugate descent has .9834 validation performance and in case of BFGS it is .9810,so BFGS performs well here also.
So, from all the above discussion it is very clear that the performance of BFGS is far beteer than rest of the two algorithms and so does we used BFGS algorithm for temperature prediction system.

5. Conclusions

A MLP neural network is used for predicting the temperature based on the training set provided to the neural network. Through the implementation of this system, it is illustrated, how an intelligent system can be efficiently integrated with a neural network prediction model to predict the temperature. Neural-networks-based ensemble models were developed and applied for hourly temperature forecasting. The experimental results show that the ensemble networks can be trained effectively without excessively compromising the performance. The ensembles can achieve good learning performance because one of the ensemble's members is able to learn from the correct learning pattern even though the patterns are statistically mixed with erroneous learning patterns.from the result it is seen that the performance of BFGS algorithm with MLP is better than Gradient Descent and Conjugate Gradient further it can be concluded that the new wireless technology heavy weather pro can be used for data gathering.

6. Future Scope

The given project can be extended for weather forecasting, by predicting the other parameters of weather which can be used to warn in natural disasters, rain forecasting which is very beneficial for farmers. Further if web connectivity is used it can be extended to predict to all over the globe by using internet, with the use of web connectivity the satellite images also can be used for forecasting.

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