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Artificial Neural Networks' Application in Weather Forecasting – Using RapidMiner

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***Abstract*-Weather forecasting is a crucial phenomenon in today's world. Though weather prediction is completely automated, with the help of tools like Weather Research & Forecasting (WRF), Advanced Research WRF (ARW), Weather Processing System (WPS), it's a ever challenging and a topic of interest because prediction is not an accurate always. Weather forecasting is a continuous, high dimensional, dynamic and complicated process because it involves many entities of the atmosphere. The parameters required to predict the weather are enormously complex such that there is uncertainty in prediction even for a short period. The property of artificial neural networks is that they not only analyze the historical data, but also learn from it for future predictions make them suitable / ideal for weather forecasting. Weather prediction can be simplified by using the artificial neural networks (ANN) with back propagation for supervised learning using the data collected at a particular station at a specified period. After training the model, they are used to predict the weather conditions. As an experimental method, the model is made known to predict the values as unknown values. The output is promising and motivates us to work more towards this goal.**

Keywords- Data Mining, Predictive analytics, ANN, Regression Techniques, Machine Learning techniques

I. INTRODUCTION

In weather forecasting, the job of meteorologist is to predict how the weather will change during a specified period, and when and what weather conditions will prevail during the period of the forecast. Actually, forecasting is highly complex and involves mathematics, thermodynamics, atmospheric physics, laws of motion, conservation of energy, hydrodynamics etc. Meteorology is the interdisciplinary scientific study of the atmosphere. So, meteorologists are continually attempting to improve the accuracy of forecasts.

To make an accurate forecast, a meteorologist must have data collected from the past. Must understand what processes are occurring in the atmosphere to produce the current weather at a particular location, which is then compared with the past data. Prediction is done by making observations of the atmosphere; i.e., mean sea level, temperature, atmospheric pressure, wind direction and speed, humidity, cloud cover, precipitation, rainfall, etc. The more complete measurement across the earth's surfaces both horizontally and vertically we experience, the better weather picture. By observing the changes that takes place to these elements over time and by comparing the changing patterns with historical patterns, a good forecasting is possible.

If meteorologists understand how the atmosphere changes over time in response to various factors; i.e., warming up on of earth's surface due to solar radiation, advection, radiation cooling at night, latent heat release during condensation, El nino., etc., and can write Numerical Weather Prediction (NWP) equations executed using computer models to visualize how the atmosphere is changing and will appear after some time. The output from these models can be used as an aid by forecasters in preparing the forecasts. The output of the computer models is by no means perfect and should never be relied on exclusively. To conclude, the output models are dependent on forecasters' sharp knowledge based on current status to predict the future weather.

Major research and development effort is ongoing for better mathematical equations and computer models, and novel ways to communicate weather information to users in a timely and reliable manner through different media in varied formats as required and expected [1].

II. RELATED WORKS

Data Mining is the extraction of hidden knowledge from data warehouses. It is a powerful technology with a great scope to analyze and predict vital information from the databases. Meteorological data are voluminous, dynamic, complex and high dimensional. Some data mining techniques are ideal for making weather predictions. Many works have been done and it is still going on as researchers find it as a promising and fruitful. Research efforts on ANNs for forecasting are considerable. The literature is vast and growing. The idea of using ANNs for forecasting is not new. The first application dates back to 1964. It is not until 1986 when the back propagation algorithm was introduced by Rumelhart et al., 1986. From there on had been much development in the use of ANNs for forecasting. In particular, this study presents some of the most extensively used data mining techniques for climate prediction.

Gurbrinder Kaur in his paper, “Meteorological Data Mining Techniques: A Survey” provides a brief overview of data mining techniques applied to weather prediction. Data mining techniques provides with a level of confidence about the predicted solutions in terms of the consistency of prediction and in terms of the frequency of correct predictions. Sarah N. Kohail,Alaa M. El-Halees in “Implementation of Data Mining Techniques for Meteorological Data Analysis (A case study for Gaza Strip)” has employed successfully to build a very important application in the field of meteorology like predicting abnormal events like hurricanes, cyclonic storms and flash flood prediction. These applications can maintain public safety and welfare. Their future work includes building adaptive and dynamic data mining methods that can learn dynamically to match the nature of rapidly changeable weather nature and sudden events. Meghali A. Kalyankar and S.J.Alaspurkar, “Data mining technique to analyse the meteorological data” have tried to extract useful knowledge from weather data by using clustering technique i.e. k-means partitioning method.

“Experimental Survey on Data Mining Techniques for Association rule mining” by Praveen Pappula, Ramesh Javvaji gives a survey on data mining techniques. More specifically, they discuss on basic data mining technique called association rule mining. Their survey provides the related research results and also explored the future directions about data mining in weather report, and it is a good reference for researchers on this topic.

Imran Maqsood, Muhammad Riaz Khan and Ajith Abraham, “An ensemble of neural networks for weather forecasting” conclude that Neural networks based ensemble models were developed and applied for hourly weather forecasting of southern Saskatchewan. The experimental results show that the ensemble networks can be trained effectively without excessively compromising the performance. “Modeling and prediction of rainfall data using data mining” by Seema Mahajan and Dr. S. K. Vij discusses about Rainfall Prediction an important crucial application of data mining techniques. The long term rainfall prediction is very useful in planning and decision making of agricultural crop pattern and water management strategy. They used Stepwise method to perform multilinear regression on these predictors is used to develop a proposed model. “Weather prediction expert system approaches (Ceng-568 Literature Survey)” by Bulent kiskac and Harun yardimci tried to give readers an overview about weather prediction phenomena, expert systems approaches, main domain specific problems, and solution methodologies. They made this research about a local airbase short-term weather prediction implementation with Case Base Reasoning KNN algorithm, Fuzzy logic and Artificial Neural Network implementation.

“Forecasting with artificial neural networks: The state of the art” by Guoqiang Zhang, B. Eddy Patuwo, Michael Y. Hu. attempted to provide a more comprehensive review of the current status of research in this area. They mainly focused on neural network modeling issues. This review aims at serving two purposes. First, it provides a general summary of the work in ANN forecasting done to date. Second, it provides guidelines for neural network modeling and fruitful areas for future research.

III. ARTIFICIAL NEURAL NETWORKS

The word network in the term 'artificial neural network' refers to the inter connections between the neurons in the different layers of each system. This system has three layers. The first layer has input neurons which send data to the second layer of neurons, and to the third layer of output neurons, via synapses. The synapses use weights to manipulate the data in the calculations.

An ANN is typically defined by three types of parameters

- The interconnection pattern between the different layers of neurons.
- The learning process for updating the weights of the interconnections.
- The activation function that converts a neuron's weighted input to its output activation.

ANN adaptively changes their synaptic weights through the process of learning. A Feed forward NN with back propagation have been used in the past for modeling and forecasting [2] [3]. Choosing the number of hidden layers in a network depends on the training and validation of data. Each neuron in the network performs two operations:

- It makes a weighted sum of its input from the input layer.
- Then, it transfers the weighted sum to its output layer using its activation function.

A. The Back Propagation Algorithm

It is training or learning algorithm also called as Feed forward Networks or multilayer perceptrons (MLP). Back propagation network learns by example. Here we train the network, by giving examples, change the network's weights and get the output (target).

i) The network is initialised by setting up all its weights to random numbers.

ii) The input pattern is applied to get the output (forward pass)

iii) Calculate the error of each neuron (target – actual value)

iv) Error is mathematically changed, to minimize it.

v) Repeat steps ii) to iv) such that target is closer to actual value (reverse pass)

Back propagation algorithm is a supervised learning method which can be divided into two phases: propagation and weight update. Until the performance of the network is satisfactory, the two phases are repeated. In this method, the output is compared with the target to compute the value of predefined error-function. This error is then fed back to the network. The algorithm then adjusts the weights of each connection in order to reduce the value of the error function. This process is repeated for a sufficiently large number of training cycles, until the network converge at a state where the error function is relatively small. At this juncture, one can conclude that the network model is ready for test phase.

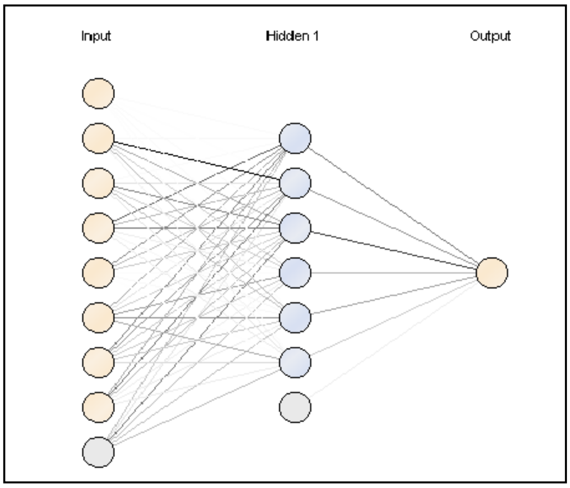

Figure 1. Neural Network Structure

B. Predictive Analytics

Weather forecasting can be modeled as a standard data mining predictive analytics problem. Predictive analytics encompasses a variety of techniques from statistics, modeling, machine learning, neural networks and data mining that analyze current and historical facts to make predictions about future, unknown events.

The methods and strategies used to conduct predictive analytics can broadly be grouped into

i) Regression Techniques [4] [6]

ii) Machine Learning techniques (MLT)

And our work focuses on MLT mainly because it emulates human cognition and learn from training examples to predict future events. In the learning process, each neuron changes its weights according to specific rules and produces result closer to the expected result [7]. ANN falls under MLT, where we use historical weather data, train the model with the known data set to predict the unknown parameters [13].

IV. TOOLS AND TECHNIQUES

A. Rapidminer 5.3

Rapid Miner is a commercial popular data mining open source tool, developed by Rapid –I, GmbH of Dortmund, Germany. RapidMiner, formerly known as YALE (Yet Another Learning Environment), was developed in 2001. RapidMiner is a software platform that provides an integrated environment for machine learning, data mining, text mining, predictive analytics and business analytics. It is used for business and industrial applications as well as for research, education, training, prototyping, and application development and integrates all steps of the data mining process including results visualization, validation and optimization. It is an easy-to-use visual environment for predictive analytics. It is the most powerful and intuitive graphical user interface for the design of analysis processes. It can easily integrate our specialized algorithms by leveraging its powerful and open extension APIs, 3-D graphs, scatter matrices, self-organizing maps. RapidMiner's advanced engine allows turning data into fully customizable, exportable charts with support for zooming, panning, and rescaling for maximum visual impact.

- Open and extensible.
- Advanced analytics at every scale perfect for big data.
- Start making predictions in 5 minutes or less with application templates.
- RapidMiner Studio runs on every major platform and operating system.
- Strong Visualizations.
- Multiple Interfaces.
- Accurate Preprocessing.
- Complete Toolbox [12].

V. IMPLEMENTATION IN RAPIDMINER

Here, we consider weather data set (1993 Jan, Feb data) collected at US international airport refer Table 1. As a case study for training the model, we used January months' data with all the prime weather attributes [8] and tried to predict February months' maximum and minimum temperature. The model is designed using RapidMiner tool, which is a basic data mining business and predictive analytical tool. While running the model, to our surprise we find that it more or less coincided with the real/actual data.

TABLE I. 1993 JAN, FEB WEATHER DATA SET

Month	Day	Dew Point	Humidity	Pressure	Tmp High	Tmp Low	Visibility	Wind Direction	Wind Speed
1	1	19.4	0.861	1017.1	25.6	22.2	15.2	31.7	5
1	2	20	0.831	1018.1	27.2	22.8	15.9	57.6	6.4
1	3	20.6	0.862	1019	26.1	22.8	15.5	72.9	6.9
1	4	21.1	0.841	1018.8	26.7	22.8	15.8	118	6
1	5	22.2	0.857	1019.1	28.3	23.3	15.8	154.7	3.3
1	6	21.7	0.877	1019.9	28.3	22.8	14.3	89.5	3.2
1	7	22.2	0.817	1017.9	28.9	24.4	14.7	138.3	4.2
1	8	22.2	0.814	1014.3	28.3	24.4	15.6	183.5	6.8
1	9	17.8	0.889	1014.3	26.1	19.4	9.9	98.8	6.2
1	10	20	0.854	1018.2	28.9	22.2	15.8	121.3	3.9
2	20	9.4	0.665	1019.5	23.9	15.6	16.7	86.7	4.8
2	21	15	0.716	1017.4	26.7	21.7	16	151.3	5.1
2	22	20	0.857	1013.9	27.2	22.2	10.9	178.5	3.9
2	23	16.1	0.819	1014.2	25	21.1	14.3	329.6	5.6
2	24	12.2	0.651	1019.5	23.9	18.9	16	52.4	7.9
2	25	12.8	0.624	1019.8	23.9	19.4	16	114.1	8.1
2	26	16.7	0.784	1017	26.1	22.2	16	164.6	5.7

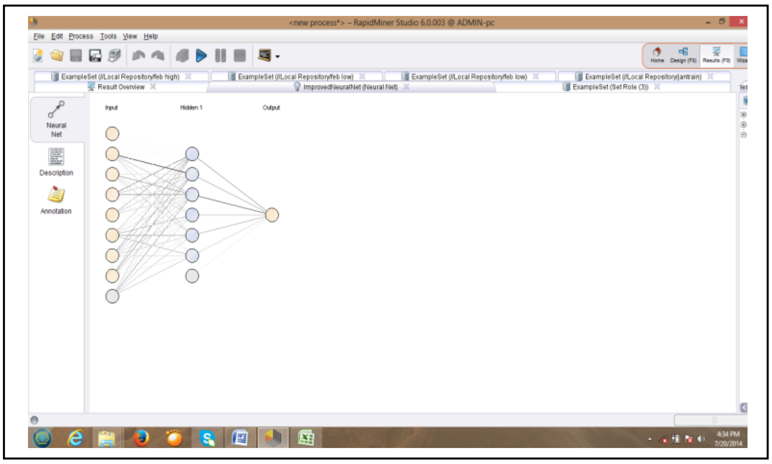

Figure 2. A Graphical view of NN for weather prediction model

NN uses hidden layer to compare all attributes in a data set to all other attributes. The circles in the graph are nodes, and the lines between the nodes are neurons. The thicker and the darker the neuron is between the nodes that exhibit the strong affinity. The graph begins on the left, with one node for each predictor attribute. Stronger neurons equate to a stronger ability by that attribute to predict [9] [10] [11].

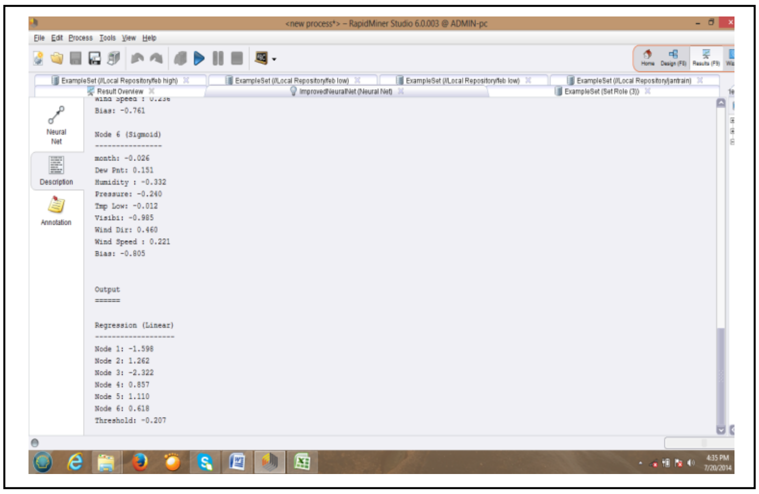

Figure 3. A Graphical view of NN for weather prediction model

VI. EXPERIMENTAL RESULTS

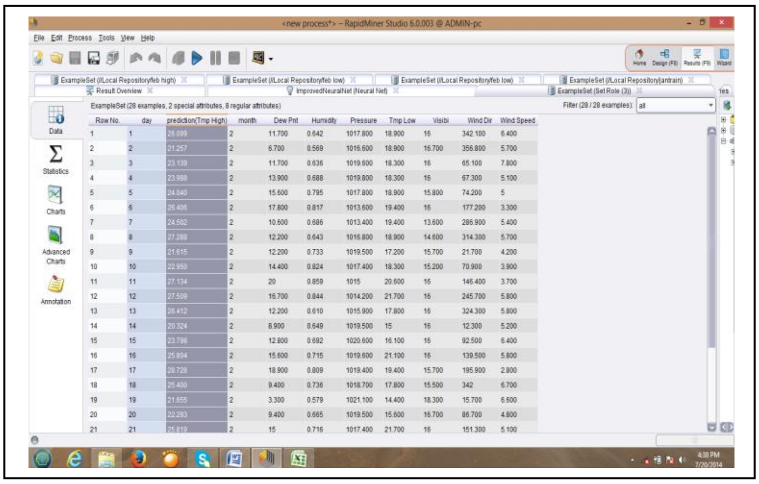

Figure 4. Screen shot predicting max. temperature of Feb 1993

The above figure is the result of running the model predicting the max. temperature of Feb' 1993. Figure 4 screen shot depicts example set of 28 examples, 2 special attributes and 8 regular attributes. It displays all the attributes given as input and one field called prediction (tmp high) which is highlighted. This output / target / predicted value generated is compared with the acutal values and it is plotted as graph, comparing both minimum and maximum values of Feb 1993. From figures 5 and 6 one can find that the deviations are narrow.

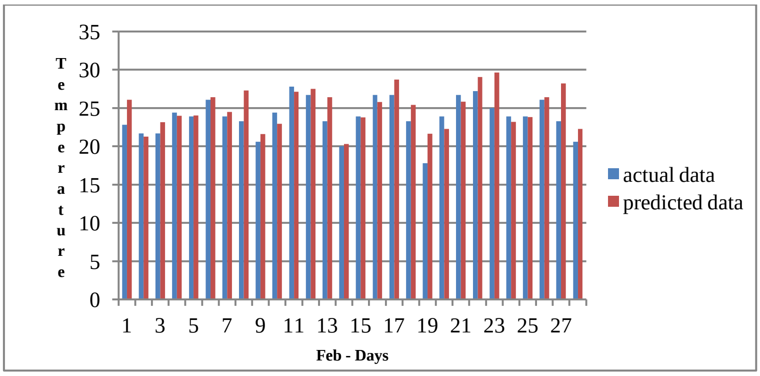

Figure 5. Graph comparing max. temperature of Feb 1993

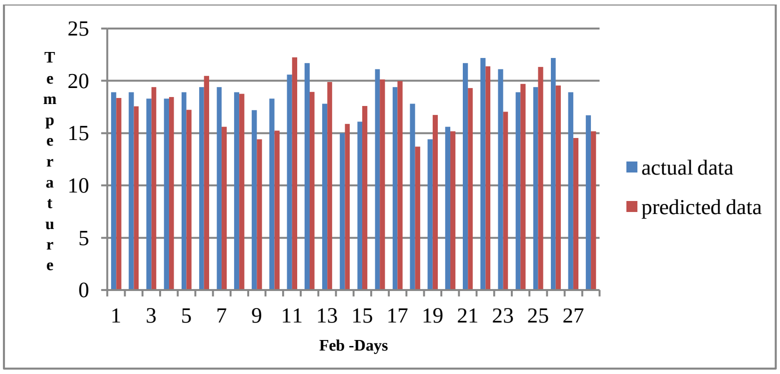

Figure 6. Graph comparing min. temperature of Feb 1993

The above graph shows the difference between the actual and predicted values. The difference can still be reduced by improving the model with increasing the training cycles, and by other parameters namely learning rate and momentum. In results perspective, we can find both a graphical model and numerical predictions.

VII. CONCLUSION

From the model we can conclude that artificial neural networks can be used as an aid to model a weather forecasting system for predicting maximum and minimum temperature. The accuracy (81.78%) was as a result of training 1000 cycles, with the learning rate of 0.3 and with momentum 0.2. The performance is measured in terms of its RMSE (Root Mean Square Error) correlation. Though there are many data mining methodologies, ANN are better at finding the strength of connections between attributes, can learn from training and exhibit intelligence in making predictions. In a nutshell the proposed model updates / adjusts attribute values, trains them, and generates nodes, with increased level of confidence percentages, even amid uncertainty in some data. The accuracy of 81.78% illustrates that a successful ANN model is developed. Also, the model can be extended to predict other weather parameters like rainfall, cyclonic storms, hurricanes, snowfall and tornadoes.

VIII. FUTURE SCOPE

Furthermore, in order to improve the efficiency of the neural network algorithms other statistical based feature selection techniques, statistical indicators can be integrated. In another perspective fuzzy techniques can be incorporated, which an inferential, probality-based approach to data comparisons is allowing to infer, based on probabilities, the strength of the relationships between attributes in the data sets and to achieve better predictability rate.

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