WEATHER FORECASTING USING SOFT COMPUTING TECHNIQUES

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ABSTRACT

Weather forecasting is the application of science and technology to predict the state of the atmosphere for a future time at a given location. It is carried out by collecting quantitative data about the current state of the atmosphere and past and/or present experiences. In this study Adaptive Neuro-Fuzzy Inference System (ANFIS) and Multi-Layer Perceptron (MLP) Artificial Neural Network (ANN) models were used to analyze metrological data sets obtained from the metrological station. The data covers a five year period (2008-2012) were for the monthly means of minimum and maximum temperature, rainfall, wind run, and relative humidity and mean sea level pressure (MSLP). The results showed that both models could be applied to weather prediction problems. The performance evaluation of the two models that was carried out on the basis of root mean square error(RMSE) showed that the ANFIS model yielded better results than the MLP ANN model with a lower prediction error.

Keywords -- ANFIS, ANN, Fuzzy Inference System, RMSE , Weather Forecasting.

I. INTRODUCTION

Weather is a continuous, data-intensive, multidimensional, dynamic and chaotic process and these properties make weather prediction a big challenge [1]. From ancient times, weather prediction has been one of the most interesting and fascinating domain of study, Scientists have been trying to forecast the meteorological characteristics using a number of methods, some of them more accurate than others. Lately, it has been discovered that data mining, can be successfully applied in this domain.

Data mining has been applied in many areas e.g. Health, Industry and Agriculture for good decision making as a result of past data collected. Today, weather prediction is made by collected quantitative data about current state of atmosphere process to project how the atmosphere will evolve. Weather forecasting entails predicting how the present state of the atmosphere will change. Present weather conditions are obtained by ground observations, observations from ships and aircraft, Doppler radar, and satellites. This information is sent to meteorological centers where the data are collected, analyzed, and made into a variety of charts, maps, and graphs in facing the prediction of the weather assumed that the state of the atmosphere in any point could be specified by seven features namely pressure, temperature, density, water content and velocity component eastward, northward and upward. [2]

Weather data can have the noises and outliers, therefore, the analysis may not be accurate. Noise is a random error or parasite that comes from the sensor network, error handwriting and so on. On the other hand, an outlier is an observation of the data that deviates from other observations so much. Therefore, we need preprocessing of the weather data to improve the quality of data for precise weather prediction.

In the data set, there are five parameters: Maximum Temperature, Minimum Temperature, Humidity and Wind speed, mean sea level pressure(MSLP) and this data are only on Delhi's weather condition. For analysis and forecast, we applied ANFIS and ANN techniques on this data and finally the performance of these two models is compared on the basis of root mean square error (RMSE).

In this paper, ANFIS MATLAB Fuzzy Logic Toolbox is used to design ANFIS model. These tools apply fuzzy inference techniques to data modeling. The ANFIS toolbox function constructs a fuzzy inference system (FIS) whose membership function parameters are tuned (adjusted) using either a back propagation algorithm alone, or in combination with the least squares methods. This allows our fuzzy systems to learn from the data they are modeling.

II. LITERATURE REVIEW ON RELATED WORK

Li. et al. in [1] proposed a rough set based neural network algorithm to solve weather prediction. The rough set method is used to get the number of fuzzy rules and their initial weights. The number of fuzzy rules decides the number of hidden layer and initial weights decide the initial values of the conclusion parameters in the learning process. The least square algorithm is used to ensure the performance of global convergence when using grads algorithms.

Oyediran et al. in [2] compared Adaptive Neuro-Fuzzy Inference System (ANFIS) and Multi-Layer Perceptron (MLP) Artificial Neural Network (ANN) models to analyze metrological data sets obtain from the metrological station. The data covers a ten year period (2002-2012) were for the monthly means of minimum and maximum temperature, rainfall, wind run, and relative humidity. The results showed that both models could be applied to weather prediction problems. The performance evaluation of the two models that was carried out showed that the ANFIS model yielded better results than the MLP ANN model with a lower prediction error.

Mathur et al. in [3] developed a feature based neural network model for Weather Forecasting. This model predict maximum temperature, minimum temperature and relative humidity using feed forward artificial neural network with back propagation for supervised learning. The trained artificial neural network was used to predict the future weather conditions.

Smith et al. in [4] developed an improved model for air temperature prediction using artificial neural networks (ANN). This model focused on developing ANN models with reduced average prediction error by increasing the number of distinct observations used in training, increasing the duration of prior weather data included in each observation and reexamining the hidden nodes used in the network.

Gholam et al. in [5] revealed that soft computing techniques are promising and efficient. The root mean square error by using Fuzzy inference system model was obtained 52 mm. Further it is also stated that unlike conventional artificial intelligence techniques the guiding principal of soft computing is to exploit tolerance for imprecision, uncertainty, robustness, partial truth to achieve tractability and better rapport with reality.

Jiong et al. in [6] explained that Neural networks offers a number of advantages, including requiring less formal statistical training, ability to implicitly detect complex nonlinear relationships between dependent and independent variables, ability to detect all possible interactions between predictor variables and the availability of multiple training algorithms. Disadvantages include its "black box" nature, greater computational burden, proneness to over-fitting and the empirical nature of model development.

III.ARTIFICIAL NEURAL NETWORK

An artificial neural network is a powerful data modeling tool that is able to capture and represent complex input/output relationships [8]. The motivation for the development of neural network technology stemmed from the desire to develop an artificial system that could perform "intelligent" tasks similar to those performed by the human brain. Artificial Neural networks resemble the human brain in the following two ways:

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

An ANN is configured for a particular application, such as pattern recognition or data classification, through a learning process. The true power and advantage of neural networks lies in their ability to represent both linear and non-linear relationships and in their ability to learn these relationships directly from the data being modeled. There are three basic elements of a neuron model. Figure 1 shows the basic elements of an ANN (the perceptron model):

i. A set of synapses connecting links, each of which is characterized by a weight or strength of its own.

ii. An adder for summing the input signals weighted by the respective synapses of the neuron

iii. An activation function for limiting the amplitude of the output of a neuron. A typical input-output relation can be expressed as shown in fig.1.

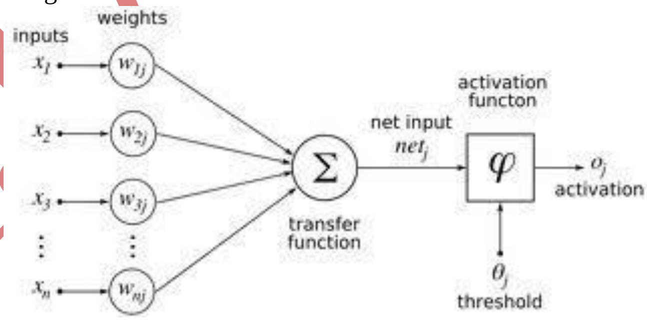

Fig.1 Analogy of Biological and Artificial Neuron

The type of transfer or activation function affects size of steps taken in weight space. ANN's architecture requires determination of the number of connection weights and the way information flows through the network. This is carried out by choosing the number of layers, number of nodes in each layer and their connectivity. The numbers of output nodes are fixed by the quantities to be estimated. The number of input nodes is dependent on the problem under consideration and the modeler's discretion to utilize domain knowledge. The number of neurons in the hidden layer is increased gradually and the performance of the network in the form of an error is monitored [8].

IV. ADAPTIVE NEURO FUZZY INFERENCE SYSTEM (ANFIS)

An adaptive network is a network of nodes and directional links. Associated with the network is a learning rule: for example back propagation. It's called adaptive because some, or all, of the nodes have parameters which affect the output of the node. The networks learn the relationship between the inputs and outputs. The ANFIS approach learns the rules and membership functions from data. The ANFIS architecture is presented in figure 2.

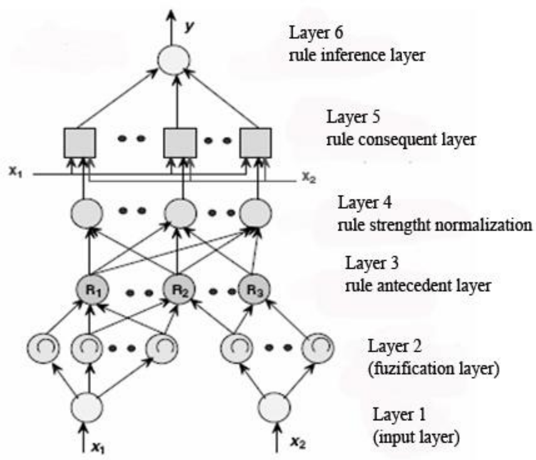

Fig.2.An ANFIS Architecture for a Two Rule Sugeno System

A Two Rule Sugeno ANFIS has rules of the form

If x is A_1 and y is B_1 THEN $f_1 = p_1x + q_1y + r_1$ (1)

If x is A_2 and y is B_2 THEN $f_2 = p_2x + q_2y + r_2$ (2)

When training the network there is a forward pass and a backward pass. The forward pass propagates the input vector through the network layer by layer. In the backward pass, the error is sent back through the network in a way similar to back propagation.

- **Layer 1**

  In Layer 1, the output of each node is

  $O_{1,i} = \mu_{B_{i-2}}(y)$ for i = 3, 4 (3)

  And $O_{1,i}(x)$ is membership functions grade for *x* and *y*. The membership functions could be any shape. Using the Gaussian membership function given by

  $\mu_A(x) = \frac{1}{1+x^2}$ (4)

- **Layer 2**

  Every node in this layer is a fixed node labeled Π, representing the firing strength of each rule and is calculated by the fuzzy AND connective of product of the incoming signals by

  $O_{2,i} = w_i = \mu_{A_i}(x)\mu_{B_i}(y)$ for i= 1, 2 (5)

Where, μA_i (x) and μB_i (x) are membership grades of fuzzy sets A, B and also w_i is firing strength of each rule.

- **Layer 3**

Every node in this layer is a fixed node labeled N, representing the normalized firing strength of each rule. The i_{th} node calculates the ratio of the i_{th} rule's firing strength to the sum of two rule's firing strengths by using eq.(6)

$$O_{3,i} = \overline{W_i} = \frac{w_i}{w_1 + w_2} \qquad i=1, 2 \qquad (6)$$

where, $\overline{W_i}$ is normalized firing strength that is the ratio of the i_{th} rule's firing strength (w_i) to the sum of the first and second rule's firing strengths (w_1, w_2).

- **Layer 4**

Every node in this layer is an adaptive node with a node function in eq.(7), indicating the contribution of i_{th} rule toward the overall output.

$$O_{4,i} = \overline{W_i} z_i = \overline{w_i}(p_i\, x + q_i\, y + r_i) \qquad (7)$$

Where, z_i is equal to $(p_i\, x + q_i\, y + r_i)$ and also p_i, q_i and r_i are consequent parameters.

- **Layer 5**

The single node in this layer is a fixed node labeled Σ, indicating the overall output as the summation of all incoming signals calculated by

$$Z = \sum_i \overline{w_i} z_i = \frac{\sum_i w_i z_i}{\sum_i w_i} \qquad (8)$$

Where, Z is the summation of all incoming signals.

V. MATERIALS AND METHODS

A. Data Preprocessing

The case data for the study was obtained from the metrological station in Delhi, Lodhi road and it covers a period of 5 years from January 2008 to December 2012. The preprocessing of the data was first carried. Missing values were replaced with zeros. The meteorological dataset , their type and description are presented in Table 1.1.

Table1.1. List of Different Input Variables

S.No.	Input Variables	Units
1.	Max. Temperature	Deg.C
2.	Min. Temperature	Deg.C
3.	Relative Humidity	%
4.	Wind speed	Kmph
5.	MSLP	hpa

B. The Neural Network Model

The objective of the training of the neural network model is to minimize a global error that measures the difference between the model output and the actual values that are defined as

$$RMSE = \sqrt{\left(\frac{1}{p}\sum_{i=1}^{p}[(P_M) - (P_{es})]^2\right)^2} \qquad (9)$$

Where, P_m is the measured value, P_{es} is the predicted (estimated) value and P is the measured values mean. Neural network is trained using Levenberg-Marquardt back propagation algorithm.

C. The Anfis Model (Adaptive Neuro-Fuzzy Inference System)

In the ANFIS model, crisp input series are converted to fuzzy inputs by developing membership functions for each input series. The Neuro-fuzzy model builds intelligence and reasoning into the system by performing Subtractive Clustering on the fuzzy sets to determine the number and type of fuzzy membership function. The membership function pattern used for the input series is of the Bell shape. The goal of ANFIS is to find a model, which will simulate correctly the inputs with the outputs data. The ANFIS Matlab Fuzzy Logic Tool Box was used for the study. The ANFIS network was trained using a back propagation learning algorithm.

D. The Performance Criteria used for Evaluating the Models

Root Mean-Squared Error-- This is simply the square root of the mean squared error. The mean-squared error gives the error value the same dimensionality as the actual and predicted values. It is given by

$$RMSE = \sqrt{\left(\frac{1}{p}\sum_{i=1}^{p}[(P_M) - (P_{es})]^2\right)^2} \qquad (10)$$

VI. RESULTS AND DISCUSSION

In this study, ANN and ANFIS models are designed to forecast various weather parameters. Weather parameters to be predicted are maximum temperature, minimum temperature, relative humidity, wind speed and MSLP. For both models yearly data is divided into four seasons as shown in table1.2. and models are trained using this seasonal data as input.

Table1.2. Yearly Data Division into Four Seasons

S. No.	Season	Duration
1.	Winter	1 December – 28 February
2.	Spring	1 March – 31 May
3.	Summer	1 June – 31 August
4.	Autumn	1 September – 30 November

The best model suitable to forecast weather is evaluated by computing the root mean square error between the exact and predicted values. Theoretically, a prediction model is accepted as ideal when RMSE is small. Results for all weather parameters in terms of RMSE are shown in following table1.3.

Table.1. 3. Performance comparison of ANFIS and ANN models

	Max.temp.	Min.temp.	Relative humidity	Wind speed	MSLP

Date	RMSE		RMSE		RMSE		RMSE		RMSE	
	ANN	ANFIS	ANN	ANFIS	ANN	ANFIS	ANN	ANFIS	ANN	ANFIS
01-01-2013	4.68	3.11	2.67	2.10	10.20	10.83	4.26	148.76	4.70	0.15
01-02-2013	3.10	2.60	2.39	2.64	15.93	16.57	2.75	76.74	6.04	1.89
01-03-2013	3.21	1.52	3.31	1.52	14.10	15.91	2.25	2.72	8.74	8.57
01-04-2013	2.39	2.20	2.80	2.43	13.10	13.51	3.20	2.23	5.73	6.81
01-05-2013	2.72	1.72	2.74	2.18	12.87	12.89	3.64	4.70	6.00	4.31
01-06-2013	2.53	2.81	2.45	2.53	12.22	12.69	3.95	4.79	4.78	30.07
01-07-2013	2.68	2.26	1.01	1.02	12.90	13.41	3.28	3.64	5.96	7.66
01-08-2013	3.00	1.93	1.27	0.99	14.67	14.69	4.42	4.26	6.71	0.11
01-09-2013	1.66	1.55	2.23	2.01	13.27	12.85	5.02	6.17	3.99	8.64
01-10-2013	1.66	1.32	2.61	2.31	6.28	8.57	2.67	2.77	5.58	25.86
01-11-2013	1.81	1.30	1.84	1.78	10.70	11.21	2.06	1.33	7.14	11.99
01-12-2013	3.02	2.20	3.09	2.49	10.12	10.40	2.14	144..20	5.03	1.00

VII.CONCLUSION

Based on the obtained results, it can be concluded that both of these models were able to capture the dynamic behavior of the weather data, resulting in a more compact and natural internal representation of the Temperature, MSLP, Wind speed and Relative humidity information contained in the weather profile.

However, regarding prediction accuracy, the ANFIS is highly appreciated for temperature forecasting. for relative humidity, wind speed and MSLP, both models are performing equally well.

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