Applications of Neural Network in Weather Forecasting

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Abstract: Weather Forecasting determines the future state of the atmosphere. To determine accurate weather forecasting is a very important problem. Weather Forecasting is the most important issue in the case of the agricultural and industrial sectors. This research presents a literature survey on weather predictions using Artificial Neural Network (ANN) and Back Propagation models. The research states that ANN is the best approach than traditional and numerical methods in case of prediction of weather forecast. Data mining technique with neural networks gives useful information for weather prediction which reduces cost as compared to other prediction models. This research is mainly explored on neural networks with back propagation approach in case of weather forecasting.

Keywords: Artificial Neural Network, Back Propagation, Data mining.

I. INTRODUCTION

One of the popular uses of science and technology is weather forecasting which is used to predict atmospheric conditions of a particular location and duration. For thousands of years, people have been trying to foretell the weather offhandedly, but have been doing so ceremoniously since the 19th century. It is done by gathering quantitative data about recent atmospheric, land and ocean conditions and using meteorology to predict how the atmosphere will change at a particular location. Weather forecasts, which were previously measured manually based primarily on changes in barometric pressure, recent climatic state, sky and cloud cover conditions, now depend on computerized models that take into account many atmospheric factors [1].

Several neural network models can be used to make weather forecasts more accurately. Daily weather data has multiple parameters such as temperature, humidity, precipitation, cloud distance and size, wind speed and direction. All of these parameters are nonlinear, but they must be processed together to determine future temperature, precipitation, humidity, or weather conditions. Such applications require a complex model and can produce the required results by generating the patterns themselves by performing self-learning using the training data given to the model.

A group of connected input or output units is called a neural network. Each connection of a neural network having a weight correlates with its computer program. This neural network is used in building prognostic models from huge databases. The human nervous system serves as the model's foundation. It is applicable for performing image comprehension, human learning, computer language, and more. These artificial networks can be used for predictive modelling, robust control, and implementations that can be instructed on datasets. Self-learning by experience can take place within networks that can draw conclusions from a complex and seemingly unrelated set of information [2].

In case of weather forecasting, an ANN model requires regional choosing for having the input data and parameters. In order for the model to produce accurate results, the input data must come from the specific region where the model is trained and tested. The number of input data supplied to the model is also used to upgrade the perfection of the model by providing outcomes with a high degree of resemblance between predicted and actual output data. The available data can contain noise and must be cleaned. Correspondingly, all parameters have different units. And normalization helps correlate input and output parameters, so they should be normalized.

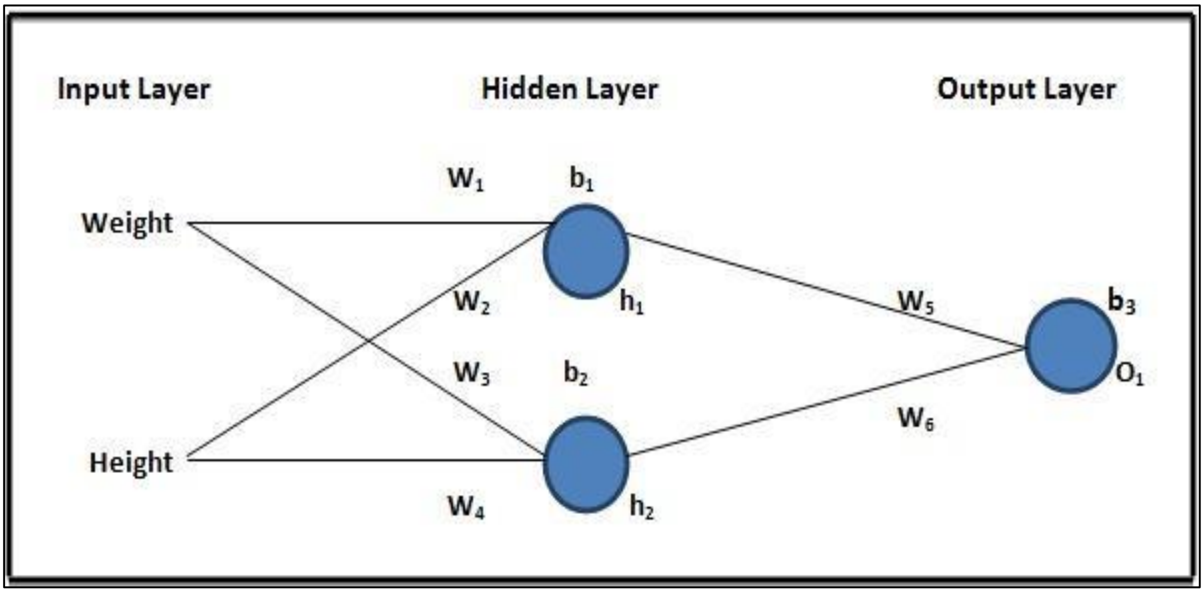

Figure 1: Layout of neural network

A neural network is nothing more than a bunch of neurons connected together. It can have any number of layers with any number of neurons in those layers. Figure 1 depicts a simple neural network model. This network model has 2 inputs, a hidden layer with 2 neurons (h_1 and h_2), and an output layer with 1 neuron (O_1).The inputs for O_1 are the outputs from h_1 and h_2. A hidden layer is present between the input layer and output layer. According to Figure 1, weight and height are taken as inputs. In case of weather forecasting, several input parameters can be considered, like temperature, relative humidity, air pressure etc. There can be multiple hidden layers which are proportional with the complexity of the performing task. The basic idea is to feed the inputs forward through the neurons in the network to get the outputs at the end.

II. LITERATURE SURVEY

Several research papers have been published that use neural network models to predict weather forecasts. Researchers have proposed several neural network models to predict weather forecasts in an efficient manner. This section covered some related tasks. In this study, De [3] introduced an artificial neural network (ANN) model to predict minimum and maximum temperatures during the rainy season only. Based on the weather conditions from January to May, we will predict the temperature for the three months of June, July and August. This is a single hidden layer model with two nodes in the hidden layer. The maximum error recorded was 5% [3].

Hayati et al.[4] used an artificial neural network (ANN) to predict the next day's temperature. They divided the data into four sections. Each section represented a season, and each season had its own separate network. The researchers used a multilayer perceptron (MLP) model used to train the network on 10 years of data (1996-2006). The resulting error varied between 0 and 2 Mean Squared Error (MSE) [4].

Babu et al.[5] studied the main algorithms for training using artificial neural networks (ANN) a nd used BackPropagation Neural (BPN) for prediction. We trained and tested an artificial neura l network using the current year's weather information including temperature, set point, humidit y, SLP, visibility, wind speed, and more. According to our research, the smallest recorded erro r was 0.0079 and the largest was 1.2916 RMSE [5].

Shuxia et al.[6] Predicted power consumption using a nonlinear network model between electri city consumption and the factors affected was obtained by training relative data of China's pow er consumption from 1980 to 2005. I was. The results show that the backpropagation neural (B PN) network using the immune algorithm is more accurate than the optimized neural network u sing the genetic algorithm [6].

Marzi et al. [7] consider solutions for predicting option prices in volatile financial markets. It validates a mathematical model based on the classical parametric Black-Scholes solution. Using the Levenberg-Marquardt back propagation technique, the neural network was trained. A number of observations were made when comparing the Neural Network (NN) hybrid model with both the Black-Scholes model and the Neural Network (NN) simple model. The first result was that the average absolute percentage error of the Neural Network (NN) hybrid model over the entire dataset was superior to both the Black-Scholes model and the Neural Network (NN) simple model [7].

Gao et al.[8] perform sales forecasting for accurate and fast results that help e-commerce businesses resolve all uncertainties related to supply and demand and reduce inventory costs. Models are proposed in extreme learning machines. By determining the Extreme Learning Machines (ELM) coefficients that are running experiments with the number of hidden nodes and various variables, the proposed method has the effect of reducing the prediction RMSE and improving accuracy and speed [8].

Harshani et al. [9] used an Ensemble Neural Network in which a finite number of her ANNs are trained for the same task and their results are combined. Performance is compared with

Back Propagation Neural (BPN) network, Radial Basis Function Network (RBFN), and General Regression Neural Network GRNN. The results show that the ENN model predicts precipitation more accurately than the individual BPN, RBFN, and GRNN. A weakness of the method proposed in this paper is that it only predicts precipitation [9].

In [10], researchers used ANNs for "one day ahead" (next day) temperature prediction. Training was performed on 65% of the data set. Tests were run on 35% of the dataset. The network has a hidden layer that uses a sigmoidal transfer function. The number of neurons and epochs were determined by trial and error. The strengths of this method are the minimal prediction error of the structures used, high performance, and reasonable prediction accuracy. The model is restricted to temperature prediction only [10].

Hall et al. [11] first developed a neural network using a two-year data set of 19 variables. This application creates her two networks, the Quantitative Precipitation Forecast (QPF) network for forecasting precipitation and the Probability of Precipitation (PoP) network for the probability or confidence of the forecast. This technology significantly improves precipitation prediction, especially in applications that require accurate results. The main drawback of this model is its focus on precipitation forecasts only.

Kaur et al.[12] describes a model that predicts hourly temperature, wind speed, and relative humidity 24 hours in advance. Training and testing are conducted separately for the winter, spring, summer and fall seasons. The authors compared multilayer perceptron networks (MLP), Radial Basis Function Networks (RBFN), Hopfield models (HFM), and ensembles of these networks. MLP was trained by back propagation. Radial Basis Function Network (RBFN) has natural unsupervised learning. As the optimal architecture, the authors proposed one hidden layer and 72 neurons for MLP network and two hidden layers with 180 neurons for RBFN. The log-sigmoid is the activation function of hidden layer entities in MLP networks. RBFN uses a Gaussian activation function. In both cases the output is a pure line. Mean Absolute Percentage Error (MAPE) is used as a measure of precision. RBFN has the best performance. RBFN and MLP have nearly the same accuracy, but MLP takes longer to train. Winter and spring have the lowest MAPE of humidity forecasts, while summer and autumn have the highest temperature forecasts. However, the ensemble performance outperformed all individual networks.

Mathur et al. [14] focuses on forecasting maximum and minimum temperatures and relative humidity using time series analysis. The network model used is a multilayer feed forward neural network with back propagation learning approach. Direct and statistical input parameters and periods are compared. 15 weeks of input data seems to be the best for predicting minimum or maximum temperatures. The input features were the maximum and minimum features respectively. So these functions are Moving Average, Exponential Moving Average, Oscillator, Rate of Change and Third Moment. The error at 15 weeks was less than 3%. The major finding is that statistical characteristics can be utilised to identify trends generally. Control parameters are Moving Average, Exponential Moving Average, Oscillator, Rate of Change and Moment. Curvature and kurtosis did not work well.

Sergio et al. [15] used an evolutionary neural network in combination with a general algorithm to predict daily temperatures. Recommended input parameters are month, day, daily precipitation, maximum or minimum temperature, maximum soil temperature, minimum soil temperature, maximum relative humidity, minimum relative humidity, solar radiation and wind speed. The accuracy is 79.49 and the error is 2 degrees. Back propagation is used for training. The authors believe that using a larger training dataset, different learning algorithms, and more wait values will improve accuracy. Shrivastava et al. show that BPN and RBFN are efficient models for predicting monsoon precipitation and other meteorological parameters in small areas. BPN and RBFN have obtained excellent solutions for long-term weather forecasting [16].

Naik et al. [17] shows the limitations of some state-of-the-art weather forecast models. The focus is on various weather forecasting models using artificial neural networks. These networks are trained with back propagation algorithms

The amount of data or information collected to train a model plays a very important role in predictive reliability. A training set is the most important unit of our project. This is the set of inputs and outputs provided by an artificial neural network.

III. APPLICATION OF BACK PROPAGATION MODEL IN WEATHER FORECASTING

There are many ways to build and implement neural networks for weather forecasting. Back propagation neural networks are a commonly used technique for training neural networks [1]. Back Propagation, short for Back Propagation of Errors, is the mechanism used to update weights by gradient descent.

Back Propagation is one of the key concepts in neural networks. Our job is to classify the data in the best possible way. To do this, we have to update the parameters and bias weights. In one training example, the back propagation algorithm computes the slope of the error function. Back propagation used as a function of a neural network. Set of methods used to efficiently train artificial neural networks following a gradient descent approach that makes use of chain rules [18].

Back propagation [17, 18] algorithms are iterative, recursive and efficient. It has been upgraded in order to improve the network until it produces the best output. It computes the slope of the error function with regard to the neural network weights. To find the minimum value of a function with the help of Gradient descent algorithm. The main motive is to reduce the difference between predictions and actual results. In science, real-world performance is fixed, so the only way to reduce the error is to change the forecast values.

Based on the Flow Diagram [16,18] in Figure 2, each step can be described as follows:

1. *Selection of stations stage:* This stage only selected the stations.
2. *Collecting climate data:* At this stage, collect climate data such as rainfall amount, humidity, temperature, weight, height etc. of a specific duration.
3. *Data processing:* The steps taken are identifying or changing data that makes data more consistent and eliminates excessive data.
4. *Prediction using Back Propagation Neural (BPN) Network:* Back propagation algorithm is applied and authorized to reduce the error of the processed data.
5. *Prediction result*: Prediction is made to know the weather forecast in the future with the Artificial Neural Network model with the most accurate Back Propagation method.

6. *Test:* Processing results after the model determination process is complete, the testing phase is carried out on the results of data processing using Matlab R2017b Software.
7. *Model:* The results of this stage are several models of artificial neural networks with the back propagation algorithm to predict the weather forecast more accurately.
8. *The model is used for prediction*: If the error of the data is not acceptable then, the data will take another approach till the error becomes acceptable and the model is used for prediction.
9. To determine whether the outcomes of the test data processing are as anticipated, a final evaluation is conducted by computing the correlation, regression, MSE, and MAE values.

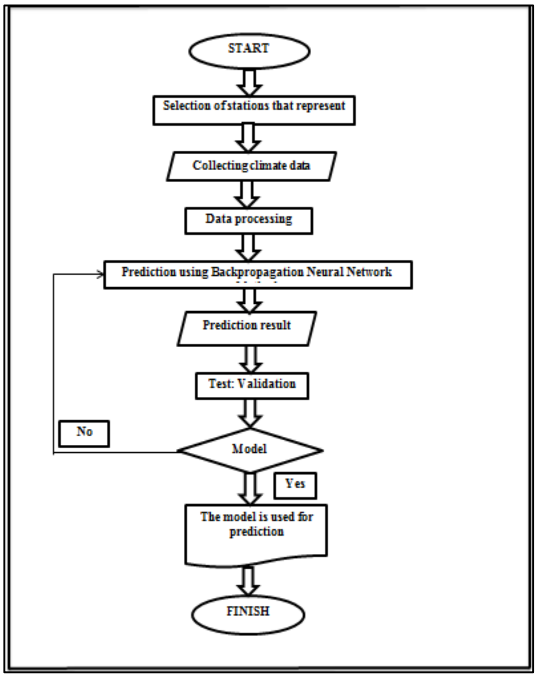

Fig. 2. Flow Diagram of Entire Plan of Work

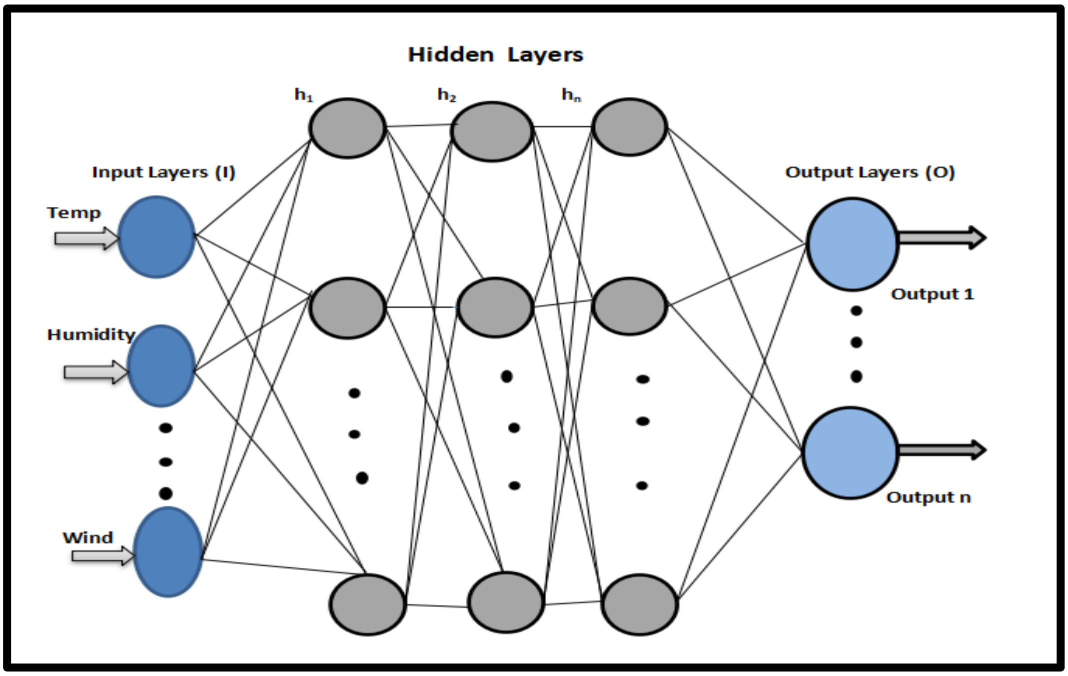

Fig. 3. Layout of Back Propagation

Figure 3 depicts the complete layout of the back propagation model. This model has 3 layers: an input layer, a hidden layer, and an output layer. Several meteorological data (temperature, humidity, wind flow, etc.) are used in the input layer. Numbers of hidden layers are varied based on the complexity level of application. The hidden layer always sits between the input and output layers. All the computations have been performed in this layer [16]. The model processes the input data using random values of weights and an activation function. This function is applied to each neuron to obtain the output for a specified data to it. Then, the output layers produce the output (predicted). Obtained output is then compared to the target output specified for the same input dataset, so the error is calculated by subtracting the predicted output from the target output. Using this error, the weights are adjusted and the whole process is repeated again for multiple iterations until reach the least error. Least errors are considered better results [16, 17].

3.1 Algorithm of Back Propagation

Algorithm 1: Back Propagation [16, 17]
Step 1: Firstly, Input layer accepts all the input through upstream path. Step 2: Inputs are matched against real weights and randomly select the weights. Step 3: Compute the output for each neuron at hidden layer and produces the output at output layer. Step 4: Estimate the error received from the output layer. Step 5: Tune the weights for producing the better output and also accurate prediction (less error). Step 6: Repeat this process until accept the desired output.

3.2 Importance of Back Propagation

The back propagation technology helps to adjust the weights of the network connections to minimize the difference between the actual output and the desired output of the net, which is calculated as a loss function. Importance of this model is defined in this section.

Back Propagation Network (BPN) [16, 17] used to simplify the network structure by removing the weighted links, so that the trained network will have the minimum effect. This method is very much applicable in deep neural networks, which is work on error-prone projects like speech and image recognition. This model has several multiple inputs using chain rules and power rules. It is used to compute the gradient of the loss function with respect to all weights in the network. It minimizes the loss function by updating the weights with the gradient optimization method [18].

IV. CONCLUSION

This paper demonstrated about neural networks that how the model applied to predict weather forecasting, and how one of the most powerful forecasting algorithms known as the back propagation algorithm works. A three-layer neural network is designed and trained using an existing dataset to obtain relationships between existing nonlinear weather parameters. The trained neural network is now able to predict future temperatures with less error.

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