Climate Change Prediction Using Artificial Neural Network

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Abstract
Climate forecasting is scientifically and technologically challenging problem around the world which requires observing and processing large amounts of climate data. Predicting the climate is important for the best and worst of climate. The aim of this paper is to predict rainfall. In this paper we use classification technique, back propagation artificial neural network for predicting rainfall using maximum and minimum temperature. The performance of this algorithm is compared using standard performance metric such as mean square error and correlation coefficient. A predictive artificial neural network model was also developed for the rainfall prediction program and the results compared with actual rainfall data for the predicted periods.

Keywords: Data mining; Rainfall; Climate; Prediction; Back propagation Artificial Neural Network.

Introduction
Climate prediction for the future is most important attribute to forecast because most of the industries as well as agriculture sectors are largely dependent on the climate conditions. Since the ancient times climate prediction is one of the fascinating and interesting domains. It is used to predict and warn about various natural disasters which are caused due to changes in climate conditions. Due to confusing nature of atmosphere, we require more computational power to predict the atmosphere for solving its complex equations. Climate forecasting may be less accurate, because of the difference between the past time and the future is more. With the help of these models we can minimize this error for predicting the most correct outcome.

The steps involved in predicting the climate are as follows:
1. Data collection such as maximum and minimum temperature
2. Data assimilation.
3. Data analysis
4. Numerical climate prediction

The various methods used in prediction of climate are:

Synoptic climate prediction
It is one of the approaches for climate prediction. It refers to the different climate elements within the specific time of the observation. For keeping the track of changing climate a meteological center prepares synoptic chart each and every day involving huge collection of climate data obtained from various climate stations.

Numerical climate prediction
It uses power of the computer for prediction of climate. Different complex programs are run on the supercomputer for providing different information of climate. But the equations used in this method are not precise. If the initial stage is not properly known then climate prediction is not accurate.

Statistical climate prediction
It is used along with the numerical methods. In this method it uses past records of climate data for predicting the future climate. The one of the purpose is to find various aspects of climate which are good indicators of future climate.

Related Work
Investigation was carried out for the problem of ensemble learning in raster classification. This problem is important in many applications such as classification in medical image processing, land cover classification in remote sensing. The problem is challenging due to the effect of class ambiguity from spatial heterogeneity. A novel spatial ensemble the framework, which is further used for partitioning a raster framework into different spatial footprints for minimizing class ambiguity of training, samples (Zhe Jiang et al. 2014). Artificial neural network approach can be used to solve nonlinear problems of regression arises in environmental modeling which includes forecasting for a short term period which also includes rainfall runoff modeling and atmospheric concentrations which leads to the pollution. The aim was to review an existing methodology for estimating predictive uncertainty as environmental datasets are redundant and noisy which describes how a predictive distribution model can be used to assess the impacts occurred due to the climate change and to improve the different decision to avoid the different impacts of it(Cawley G.C et al. 2006). Investigation was carried out to find relation between different metrological factors and Newcastle disease and the different key factors that access the Newcastle diseases has been determined. For this Newcastle disease forecasting model was
been built and apply Back Propagation neural network classification technique has been used in animal disease forecasting for their research (Hongbin Wang et al. 2009). For discovery covariate which is based on a Poisson description with high frequency Bayesian framework and Sparse regression model of hierarchical Bayesian was used to identify the co-variates which affects the precipitation frequency which are collected from the various observations at different stations over many different climatologically regions which are in the US continental (Debasish Das et al. 2014). The For combination and representation Dempster-Shafer theory of evidence was used for uncertainty which has been seen in different sources. Bayesian and Dempster-Shafer approaches for uncertainty modeling are used for the prediction hydrologic drought which comes under climate change (Deepashree Raje and P.P. Mujumdar 2010). A dynamic networks-based methodology Spatio-Temporal Physical System is used in advance future prediction for emerging extreme events of dynamic tracks such as hurricanes or forest fires (Huseyin Sencan et al. 2012).

Using data such precipitation, temperature, pressure the study was carried out for modeling monthly speed values, which also includes how this factors are important for the estimation of these different variables. The parameters such as pressure and precipitation have the approximation values of 40% and 10% respectively (M. A. Ghorbani et al. 2013). A comparison was made between the performances through prediction evapotranspiration by the pan evaporation method and the FAO56 Penman-Monteith method using the artificial neural network. The relationship between evaporation meteorological factors is determined, an artificial neural network was used (Seema Chauhan-R. K. Shrivastava 2008). The data mining technique (artificial neural network) was used to predict the lo future rainfall of the local-scale from three different coarse-scale GCMs. The case study has been selected urban drainage catchment for the area of northwestern England. For understanding and quantifying the potential hazard from surface flooding, the final assessment was done with the help of risk assessment and calculated local rainfall methodology (M. Abdellatif et al. 2015).

This paper work is based on solar forecasting of solar radiation which affects the production of photovoltaic. The variation in the climate and is features which makes it difficult to predict solar radiation. The quantity of solar radiation of depends on latitude of the different geographical locations and its different characteristics. The Extreme Learning Machine has been used for training a neural network model which is used for the predicting the solar illuminance. This trained neural network has been challenged on solar illuminance of two year ground (Ferrari, S. et al. 2012). Data mining approach for rainfall prediction was used. The Bayesian classification technique was used and results in a good prediction performance, and can be used for class prediction problems. The Bayesian prediction model can easily learn new classes. The accuracy increases with the increase of learning data (Nikam, V.B and Meshram, B.B 2013). The Neural Network has different types of algorithm one of which is back propagation neural network. This technique was used for predicting the temperature. The main advantage of the BPN neural network method is that it can be used to fairly To approximate a large values class of functions the back propagation neural network method can be used for effective prediction. This method is better than numerical differentiation (I. Kadar Shereef, Dr. S. Santhosh, 2011). The Empirical method and Dynamical method are mainly two approaches for predicting rainfall. The approach here is empirical approach which is based on analysis of historical data. One of the most used approaches is empirical approach for climate predictions are artificial neural network, regression, fuzzy logic. This paper use data mining technique which includes classification and clustering techniques for rainfall prediction. This paper applied neural network for rainfall prediction and the neural network Bayesian regularization has been applied in the implementation (Jyothis Joseph, Ratheesh T K 2013). In the world which contain non homogenous datasets the framework for learning robust predictive models does not contains the enough number of training samples were presented. Remote sensing for forest cover estimates has been demonstrated by using this framework (Anuj Karpate 2015). In this paper they have used evaluation of feed forward back propagation neural network. This back propagation model has been compared to other conventional methods. A new approach has been adopted by using few variables. Results show that BP performs better than BCR and RMBF methods (S’Traore 2015).

Methodology

Artificial Neural Network

A neural network is the tool that is used for data modeling and is used to find out the relationship between inputs and outputs which may be complex. The idea of neural network technology is inspired by human biological human nervous system which includes human brain which processes the information. It is used to perform intelligent tasks which are as similar to the task which is performed by human brain. Neural Network almost performs similar task same as performed by human brain. The task which is similar is as given below:

- Like human brain network gains knowledge by learning and training.
- It uses inter-neuron connection strengths to store knowledge which is called synaptic weights

Neural Network is a structure or a network of interconnected units of large number of neurons. The local computation has been carried out based on the characteristics of input and output neurons which implements the function for this calculation. The function (weighted sums of inputs) which produces an output if it exceeds a given threshold. The output can use as an input to other neurons in the network. This process repeated until a final output is produced.

Neural network are used for representing the relationships between linear and non-linear from the data directly which has being modeled. A neural network model is a network of neurons. It is used to map the relationship between a given set of data or is used among the data. The data model collects the data from different sources as input. This input data is known as training set. After training the input data, the classification,
prediction, and simulation are performed by neural network on new data from similar sources.

![Neural Network block diagram](Image)

**Figure 1:** Neural Network block diagram

Different types of neural networks are as follows:
1. Feed forward Neural Network
2. Hopfield Neural Network
3. Radial Basis Function (RBF) Neural Network
4. Recurrent Neural Networks

**Back Propagation Neural Network**

Our method for predicting the rainfall is Back propagation neural network. The network consists of at least three layers (multi layer perception): the input layer, at least one hidden layer which is also known as intermediate hidden layer and the output layer. In this model units are connected in feed forward fashion, input units are connected with units of hidden layer and hidden layer units are connected with the units of output layer. The input pattern is propagated in feed forward direction towards the output through the input layer-to-hidden layer and hidden layer-to-output layer weights when a backpropagation network is to be cycled.

The name of algorithm itself suggest that the errors propagate backward direction from output layer nodes to nodes of hidden layer and then from hidden layer nodes to the nodes of input layer. Back propagation algorithm is used to determine gradient of the error of the neural network with respect to the modified weights of the networks. To minimizing the errors this calculated gradient is used which will be helpful that prediction is nearby to actual output. The proposed method for predicting Rainfall by using Back propagation Neural Network is tested by using huge dataset. The predicted values of rainfall are compared with the actual rainfall data of the particular year region wise. So this will be helpful to the meteorologist to predict the future weather easily and accurately.

**Back Propagation Approach**

**Phases in Back propagation Technique:**

There are two main steps involved in back propagation algorithm (Baboo S.S. and Shereef I.K) which is given as follows:
1. Propagation of weights
2. Updating of weights

**Step1: Propagation of weights**

The propagation in neural network involves different steps which are given as follows:

1. Training pattern’s input is propagated in forward direction in the neural network is used to generation the output activation
2. This activation outputs are back propagated and training patterns of the targets are used to calculate the deltas for all outputs nodes and hidden nodes of the artificial neural network

**Step2: Updating of weights**

1. The output delta which has been calculated is multiplied with input activation for the calculation of gradient for that particular weight
2. After adding the ratio with the weight it is brought in the direction of gradient
3. As it impacts the learning of artificial neural network, this ratio is essential. This learning of artificial neural network is called learning rate. To find out where the error is increasing the sign of gradient is essential which the reason to update weights in opposite direction is. These steps are repeated until we get the correct value for the predicted rainfall.

**i. Learning modes in artificial neural network**

There are two modes used for learning in an artificial neural network one is batch learning and other is online learning modes. In batch learning mode of artificial neural network propagation is done before weight updating and in online learning mode of artificial neural network propagation is done after the weight updating.

**ii. Algorithm for Backward Propagation**

The algorithm for a three-layer network model (that is for one hidden layer) is given as:

**Step 1:** All the inputs Weights in artificial neural network are initialized and

**Step 2:** Do till criterion satisfies

**Step 3:** In the training set for each e

\[ O = \text{denotes predicted output of neural network (network, e)}; // \text{forward pass} \]

\[ T = \text{denotes actual output of neural network for e} \]

**Step 4:** Then the error is calculated between actual output and neural network predicted output at the output nodes

**Step 5:** Calculate the delta values for hidden layer through the weights from hidden layer nodes to output layer nodes //propagation in backward direction

**Step 6:** Calculate the delta values for hidden layer through the weights from input layer nodes to the hidden layer nodes; // propagation in backward direction

**Step 7:** After calculation of weights, updating are done in network

**Step 8:** Do till criterion satisfies

**Step 9:** Return the network
Approach for Rainfall Prediction

1. In every layer the output of each neuron is moved to every other neurons in that layer.
2. Every neuron has its input weight.
3. In input layer, input values are fixed i.e. assuming the weights for each input bias in the input fixed.
4. The output is calculated using inputs values at the input layer nodes and the output of this neurons acts as an input to the other input layer nodes which are hidden layer nodes and output layer nodes values.
5. The Back Propagation Neural Network may contain any number of hidden layer but it is compulsory to have one input and one output layer.

In this Network the number of neurons is equal to the number of inputs provided at the input layer. The number of neurons present at the output side is decided by the number of output needed by the user. In this network, total number of hidden layers and neuron in the hidden layer are not fixed i.e. they can vary according to data and configuration of network. The performance of the network decreases when hidden layers are added to the network but the same hidden layers are used to evaluate complex patterns. The network configuration has a single hidden layer, but if the neural network model is not learning well then the other hidden layers can be added to the network accordingly.

The inputs to the neural network are as follows:
- Rainfall
- Maximum Temperature
- Minimum Temperature

Back propagation is an iterative process that moves in backwards direction from output layer to input layer through hidden layer until the first layer of network is reached. Suppose the error at the output layer is known then it is easy to determine the changes in the weights of input neurons, to minimize the error.

The error of the previous layer output can be calculated using back propagation, by taking the output of current layer as the feedback value. Now apply this iteration: start from the output layer and then calculate the changes of weights of this output layer. Then after doing this determine error in the output layer and its previous layer.

The given below equation is a back propagation equation which helps to calculate the partial derivative of the $E^p$ error w.r.t $y^i$ i.e. (the activation value) up to the $n^{th}$ layer. Now calculate the partial derivative of the error w.r.t output of the last layer neurons. The formula for error calculation is as follow:

$$E^p_n = \frac{1}{2} \sum_{i} (y^i_n - T^i_n)^2$$  \hspace{1cm} (1)

Taking the partial derivative of given equation (1)

$$\frac{\partial E^p_n}{\partial y^i_n} = x^i_n - T^i_n$$  \hspace{1cm} (2)

This initial value of back propagation neural network is calculated by using equation (2). If the values present at the right side of the equation (2) in numeric value then the derivative is also numeric. These numeric values of the derivative are used to calculate the change which has occurred in the weights by using equation (3) and (4):

$$\frac{\partial E^p_n}{\partial \sigma^i_n} = G(\sigma^i_n) \frac{\partial E^p_n}{\partial y^i_n}$$  \hspace{1cm} (3)

Here $G(\sigma^i_n)$ denotes the derivative of the function

$$\frac{\partial E^p_n}{\partial W^i_n} = \sum W^k_n \frac{\partial E^p_n}{\partial y^i_n}$$  \hspace{1cm} (4)

Then, again using equations (2) and (3) for calculating the previous layer nodes errors, now using the below equation (5):

$$\frac{\partial E^p_{n-1}}{\partial y^i_{n-1}} = \sum W^i_n \frac{\partial E^p_n}{\partial y^i_n}$$  \hspace{1cm} (5)

The starting values for immediate previous layer are calculated using the values obtained from equations (5). For the previous layer the numeric values that is calculated from equation (5) is used in equation (3),(4) and (5).

The equation (4) represent the change in weight occurred in the current layer $n$, and the weight is updated by using the given below formula:

$$W^i_n^{\text{new}} = (W^i_n^{\text{old}}) + \eta \frac{\partial E^p_n}{\partial W^i_n}$$  \hspace{1cm} (6)

Here \(\eta\) shows the “rate of learning”.

Results and Discussion

To evaluate the proposed neural network model the dataset is taken from Indian Institute of Tropical Meteorology [16]. This dataset contains minimum, maximum temperature and actual rainfall data particular period of time. The data which we have used for prediction is of North-East India and then the analysis was done using neural network model for the year 2015 and then the predicted values were compared with actual values of rainfall (in Degree Centigrade). The graph for the year 2015 is as given below.
The results are compared with previous predicted values of rainfall of Chennai region for the year 1901-2001. Here the mean of maximum temperature, minimum temperature and rainfall were given and the predicted values of rainfall are compared with actual value of rainfall (in Centigrade). The above graph is for Chennai region for rainfall prediction.

Conclusion

In this study, it can be concluded that a feed-forward artificial neural network model using back-propagation algorithm is developed to predict the rainfall using minimum and maximum temperature. The outputs show that an appropriate accuracy can be achieved by this method. The artificial back propagation approach for climate change prediction is calculate the efficient and accurate results of rainfall prediction and can be used as an alternative method for prediction of other climate changes. However in future it can be extended to predict climate change with other parameters for large region.

References


