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Application of ANN technique for rainfall forecasting over Iraq

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Abstract
Rainfall prediction for 5 climatic stations covering Iraq using Artificial Neural Network (ANN) technique has presented. Data records extend for the period 1937 to 2010 was used to forecast the next ten years for each station. Two prediction approaches were used with the ANN, Bipolar Sigmoid (BS) and Hyperbolic Tangent (HT) to simulate the predication with Mean Square Error (MSE) of 0.1. It reveals the possible success for 4 years is more successful than 10 years forecasting .This conclusion is compatible with continuity of the Autocorrelation Function (ACF) lag graph for the time series. HT found to give better estimation than BS activation function.

Keywords: Meteorology; Precipitation; Rain forecasting.

1. Introduction

Rainfall prediction was and still been challenging issue for meteorologists and other workers dealing with atmospheric science. In most cases Autoregressive Moving Average (ARMA) and similar statistical approaches and models were approved to give" justified reasonable" but not enough reliably accurate. It is for this reason the ANN represents the best alternative so far. Since then, ANNs have found increasing use in diverse disciplines ranging over perhaps all branches of science and engineering. Such methods encourage the researchers to utilize in several applications. In the last years, researchers have begun to investigate the potential ANN as a tool for simulation of behavior of systems that are governed by nonlinear multivariate, generally unknown.

Neural network is particularly useful when problems are driven rather by data than by concept or theory. To date Neural networks have yielded many successful applications in many areas, as diverse as engineering, geology, and physics indeed, anywhere that there are problems of prediction or classification, neural network are being introduced. ANN models have been applied to problems involving runoff forecasting and weather predictions [1], ANNs have been applied to groundwater reclamation problems [2], predicting average air temperature [3], predicting precipitation [4].

Prediction of non-linear phenomenon are an important application of ANNs such as wind speed [5, 6] and have recently been used successfully in prediction of wind speed-energy [7-10]. ANNs which are trained on a time series are supported to achieve firstly to predict the time series many time steps ahead and secondly to learn the rule which has produced. the technique of neural networks is employed to forecast daily, weekly and monthly of the wind speed [11]. Both feed forward as well as recurrent networks are used and trained on past data in the autoregressive manner using back propagation and cascade correlation algorithms. It was concluded that the cascade correlation algorithms yield more

accurate forecasts compared to that of back propagation with critical analysis and review on ANNs. Recent research activities in forecasting with ANNs could be promising alternatives to the traditional ARMA structure. The hybrid ARMA and ANN model also presented as a solution for complex systems [12] such as model identifications of ARMA using genetic algorithms [13], stock pricing using hybrid ARMA and support vector machines models [14], and intelligent techniques time series prediction [15].

The need to accurate forecasting of rainfall has been one of the most important issues in hydrological, hydrometeorological research, particularly in Iraq which are suffering from severe extensive drought during the last decades. Iraq is a semi-desert, characterized by hot dry summers, moderate winters and very little rainfall. It has only two seasons: a mild winter from November to April and a hot summer from May to October. The difference between these seasons is a variation in daytime temperature. Average annual temperature ranges between minimum of 0°C in winter and maximum of 48°C in summer. Climate of Iraq is generally characterized by its large variation in temperature, rainfall and other meteorological parameters both in time and space, which has an average annual precipitation of about 200 mm, ranging between 1200 mm in the extreme northeast to 50 mm in the southwest [16].

Despite of the need to a relatively reliable rainfall prediction in the country, studies are very rare in this respect. Routine, unpublished, not verified works were carried out by the State Meteorological and Seismic Monitoring Organization of Iraq. Last decade some trials to predict the rain rate from the available data records by applying ARIMA model, but those predictions were neither tested nor verified [17].

The target of this work is to give acceptable forecasting of the rainfall for five different distributed stations covering Iraq by using the ANN. These Stations are: Mosul .in the north, Baghdad, in the central part of Iraq, Rutba to the west, Nasriyah to the south and Basrah in the extreme south. All stations data were processed and analyzed with BS and HT algorithms. Target of 0.1 were used to forecast the rainfall for 10 years period with 12 inputs and 11 hidden layers. A feed forward network equipped with back propagation algorithm was adopted, to forecast the total rainfall for the next 10 years. Additionally, predictions with multiple linear regression (MLR) models were compared to those of ANN. in order to evaluate the rainfall forecast a statistical analyses were performed. Tests for the actual, BS and HT for four years of Basrah station are compared and predictability error is calculated according to the formula in equations (1) and (2):

$$RMSE = \sqrt{\frac{\sum \left(x_p - x_a\right)^2}{N}} \tag{1}$$

$$E = \frac{x_p - x_a}{x_a} \times 100 \tag{2}$$

where x_a and x_p are the actual and predicted measurements.

2. ANN model

An ANN is a massively parallel-distributed processor that has a natural propensity for storing the experimental knowledge and making it available for further use to understand the processes and to solve the associated problems has led to the development of ANN technique. Neural networks essentially involve nonlinear modeling approach that provides a fairly accurate universal approximation to any function. Its power comes from the parallel processing of the information from data. No prior assumption of the model form is required in the model building process.

Instead, the network model is largely determined by the characteristics of the data. Single hidden layer feed forward network is the most widely used model form for time series modeling and forecasting. The back propagation network BPN is one of the neural network algorithm which was formalized in mid of 1980s [18-20] etc. It has been extensively used for prediction that consists of two passes; a forward pass and a backward pass. In the forward pass the input is applied to input layer and its effect is propagated through network, layer by layer Figure 1. The net effect is computed as the weighted sum of the output of the neurons of the previous layer. The sum of squared deviation of the output from the target value at the

nodes of the output layer defines the error signal that is to be propagated back to previous layers such that the parameters are adjusted to minimize the error in further computations.

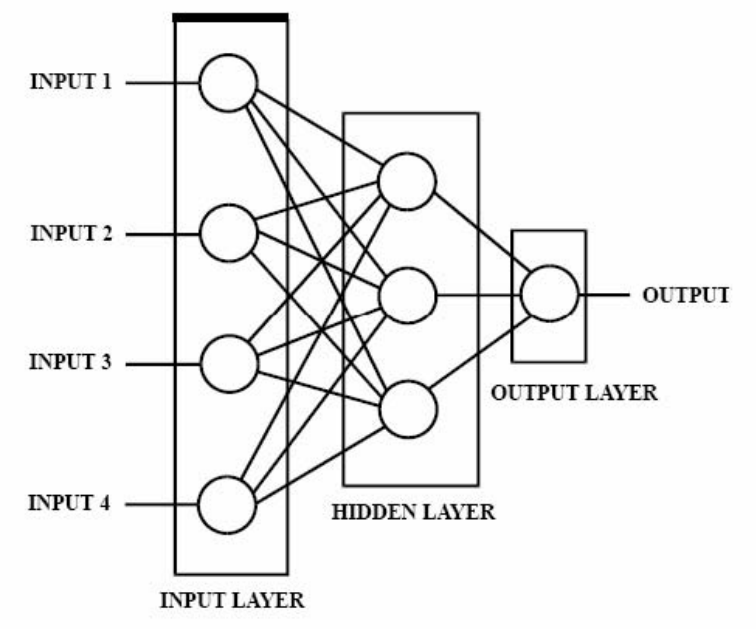

Figure 1. Artificial Neural Network

3. Results and discussion

3.1 Prediction of annual rainfall totals

Results of ANN prediction and forecasting for ten years are given in Figure 2, both BS and HT are given for the five stations. It's clearly shown that the actual rainfall data graphs 1937-2008 is completely matched with the predicted one while the forecasted next ten years shows some discrepancy between the BS and HT.

The test which covers the period 1937-2009 shows clearly that the four years forecasting for Basrah is close to the actual recorded data for both BS and HT methods. Table 1 shows a comparison between MSE of BS and HT from the actual readings.

Table 1. Predictability absolute percentage error of ANN for Basrah rainfall

year	BS	HT
2006	13.21%	20.68%
2007	16.54%	42.44%
2008	64.17%	1.49%
2009	33.33%	13.30%

Absolute percentage error ranges between (13.21%) to (64.17%) for bipolar sigmoid function with a mean of (22.81%) and (1.49%) to (42.44%%) for hyperbolic tangent with a mean of (15.58%), indicating likelihood of the hyperbolic tangent function in the prediction. These results may favor the use of hyperbolic tangent function as an activation function.

3.2 Spectral analysis

Autocorrelation Function (ACF) has been calculated for the five stations to establish whether rainfall may bear any significant periodicity of some physical meaning. An example plot for Basrah and Nasiriyah stations is given in Figure 3. It is clear that this periodicity is significant on 95% level of significance; however, the sort of regular peaks which have a period of 5-7 years are more probably the effect of the solar cycle.

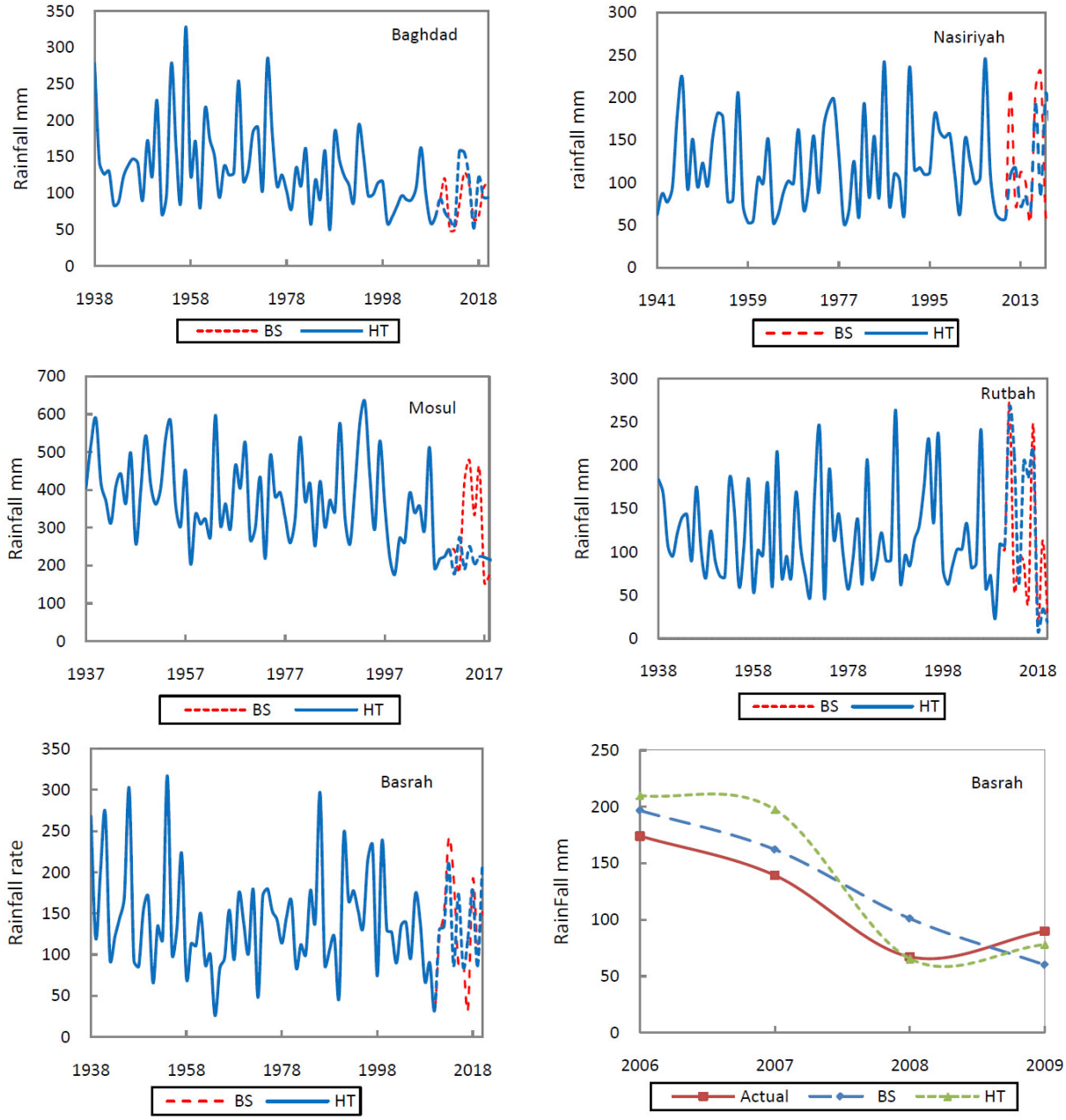

Figure 2. Rainfall forecasting using BS and HT for the five stations

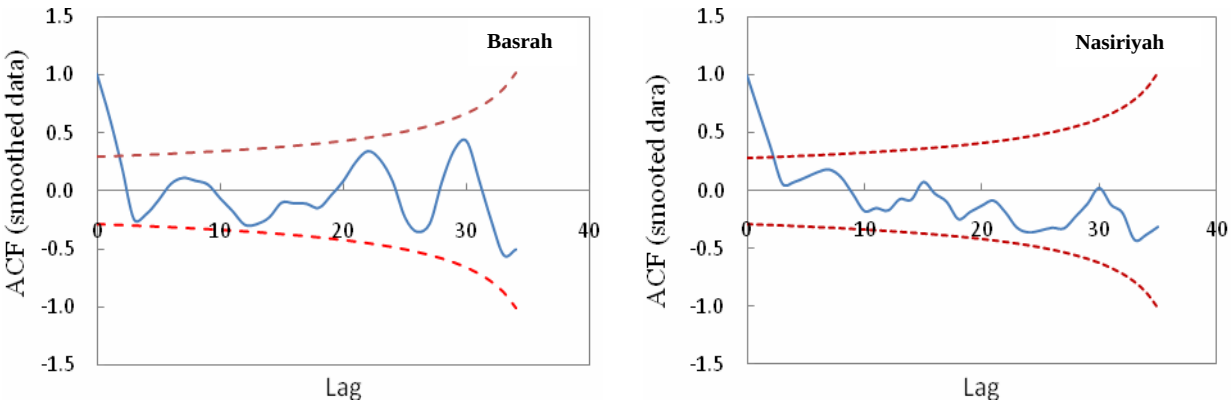

Figure 3. Autocorrelation factor for Basrah and Nasiriyah stations

4. Conclusion

In this work, it has been attempted to evaluate amount of the annual rainfall forecasting for 5 stations in Iraq based on Artificial Neural Network (ANN). As the predictability error percentage values on test data are comparatively low, the prediction model was reliable. There have been some deviations of the predicted rainfall value from the actual as climate and rainfall predication involves tremendous amount of imprecision and uncertainty, particularly when the prediction period exceeds 4 years.

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