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PREDICTION OF DHAKA TEMPERATURE BASED ON SOFT COMPUTING APPROACHES

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ABSTRACT

Soft computing forecasting tools play an important role to forecast many complicated systems. In this paper, an effort has been made to use soft computing approaches to predict Dhaka daily temperatures for the period of 28 February 1945 to 27 August 2006. We have selected the fuzzy neuro model, the neuro genetic algorithm model as soft computing techniques. To compare results, a popular time series statistical technique, namely autoregressive integrated moving average model is selected and based on error analysis, a suitable model to predict temperature for the Dhaka city is proposed. The performance comparisons of different models due to root mean square error, correlation coefficient and coefficient of determination between observed and predicted temperatures indicate that the neuro genetic algorithm model predicts temperatures with maximum accuracy, followed by the fuzzy neuro model. Our believe findings of this paper will be useful for those who are interested about Bangladeshi important atmospheric parameter, namely temperature.

JEL CODES
C22, C24, C45, C53

KEYWORDS
Artificial neural network, Genetic algorithm, Prediction, Soft computing, Statistical error measures.

1. INTRODUCTION

Forecasting is a technique of knowing what may happen to a system when certain conditions continue (or continue to change). In recent years, soft computing techniques are being increasingly used for forecasting systems. For examples, see Mandal et.al (2008), Zhang and Knoll (2001), Chaudhuri and Chattopadhyay (2005) and others. These techniques have opened up new avenues to the forecasters of complex systems. The basic philosophy of these techniques is that they build prediction systems from input-output patterns directly without using any prior information. Soft computing models composed of fuzzy logic, neural network, genetic algorithm etc. Over the years, the application of neural network in various areas (Cook and Wolfe (1991), Dawson and Wilby (1998) and others) has been growing in acceptance. Given sufficient input-output data, this network is able to approximate any function to arbitrary accuracy. Fuzzy logic is another area that has been applied successfully in recent years (Nayak et al. (2005), Singh (2007) and others). Another area of soft computing is genetic algorithm (GA) (Maritza (2009), Sen and Oztopal (2001) and others), is a global search algorithm based on the principle of 'survival of the fittest'. Most of times, these three components are combined in different ways to form models like fuzzy-neuro model, neuro-GA model etc. In literature, all of these combinations are widely used in prediction of systems. For example, neural network and fuzzy logic models are proven to be effective when used on their owns, the individual strengths of each approach have been integrated to construct a powerful intelligent system called neuro fuzzy system. Many researchers have (Nayak et al (2004), Dounis et al. (1997) and others) applied an adaptive neuro fuzzy inference system (ANFIS) for many systems modeling. The results were highly promising and a comparative analysis suggests that ANFIS outperforms than the independent neural network and the fuzzy logic models in terms of computational speed, forecast errors, efficiency etc. On the other hand, merging of GA and neural network will lead to significantly better intelligent systems than relying on neural network or GA alone (Khan et al. (2008), Lin (2004) and others). This means, find first a neural network model and then update the model using GA. The purpose of this paper is to forecast important meteorological parameter namely temperature using soft computing methodologies. It is well known that prediction of meteorological variable temperature is very important because it affects our daily lives in many ways. For example, forecasts based on temperature is important for agricultural planning, water resources management and also forecasting other important meteorological variables like rainfall, humidity wind speed etc. Temperature forecasts are used by utility companies to estimate their demands over coming days. Forecasting with 100% accuracy may be impossible, but we can do our best to reduce forecasting errors. To solve forecasting problems, many researchers (Chaudhuri and Chattopadhyay (2005), Nayak et al (2005), Maritza (2009) and others) have proposed soft computing models. This paper presents a comparative study of soft computing models, namely neuro-fuzzy model, neuro-GA model and a statistical model to forecast temperature of Dhaka city. Other meteorological variables are left for future research. We have chosen the autoregressive integrated moving average model as a statistical model. The reason is to choose this model for small forecasting errors and efficiency than other time series statistical models. Mounting empirical works (Chaudhuri and Chattopadhyay (2005), Maritza (2009), Denis et al (1997) and many others) have been carried out to forecast temperatures using various forecasting models in context of various countries. Although studies (Mondal and Shahid (2004) and others) have been conducted to predict temperature for other cities of Bangladesh, to our knowledge, no comparative work is available to predict temperature under the soft computing models for the Dhaka city. We have considered this issue in this paper, which is planned as follows: The next section explains data series and data properties. The methods used to forecast temperature for Dhaka city is described in section 3. We provide evaluation criteria and our experimental results in section 4. Finally, conclusions and some suggested future works are given in Section 5.

2. DATA

Data under investigation are the daily minimum (MinTem) and maximum (MaxTem) temperatures of the Dhaka city (collected from: ftp://ftp.ncdc.noaa.gov/pub/data/ghcn/v2), over the period of 28 February 1945 to 27 August 2006 for a total of 6469 observations. The data sets are shown in Figure 1. To understand behaviors of the MinTem and MaxTem variables, summary statistics are reported in Table 1. For example, mean and SD for MinTem shows us minimum temperatures are ranging 16.8^{0}C to 27^{0}C. Skewed and kurtosis measures indicate that temperatures pattern do not follow the normal distribution.

FIGURE 1: TIME PLOTS OF MINIMUM AND MAXIMUM DHAKA CITY TEMPERATURES

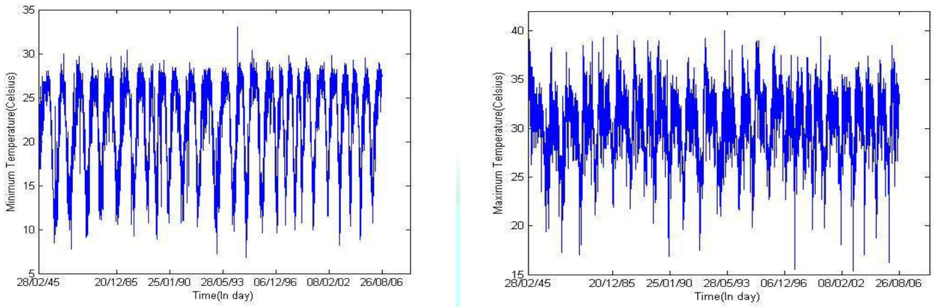


TABLE 1: SUMMARY STATISTICS OF DHAKA CITY TEMPERATURE

Statistics	MinTem (^{0}C)	MaxTem(^{0}C)
Mean	21.9	30.6
Standard deviation	5.1	3.4
Skewness	-0.66	-0.53
Kurtosis	2.21	3.28

Various methods for forecasting when series is linear or non-linear are available in literature. The method, a forecaster chooses depends upon the experience of the forecaster, the amount of information available to the forecaster and the degree of accuracy or confidence needed in the forecast. To select appropriate forecasting method, first we have selected statistical diagnostic tests to 'diagnose' problems with the model (see the next section) that we are using for forecasting. These tests are based on the ordinary least square method residuals. The statistical test proposed by Engle (1982) is used to test the presence of non-linear dependence. In addition, normality test proposed by Jarque-Bera (1980) and serial correlation test proposed by Ljung-Box (1978) are applied to

TABLE 2: DIAGNOSTIC TESTS RESULTS AT THE 5% SIGNIFICANCE LEVEL

Statistics	MinTem (^{0}C)	MaxTem(^{0}C)
Jarque and Bera Statistic	50.7079	31.2763
p-value	0.0000	0.0000
Ljung and Box Statistic	56.57	43.56
p-value	0.0000	0.0000
Engle statistic	59.79	45.09
p-value	0.0000	0.0000

see whether other important noises (peculiarities) such as non-normality and series correlation are present in the series or not. Details of the diagnostic test procedures see Thomas (1997). Diagnostic test results are tabulated in Table 2. We found that the Engle test exhibits nonlinearities in temperatures. The Jarque-Bera test rejects the null hypothesis of normality. According to the Ljung-Box statistic, there is no relevant autocorrelation for temperatures.

3. TECHNIQUES USED TO PREDICT TEMPERATURE

Since Table 2 tests results show us that the chosen variables are non-linear, we have selected non-linear forecasting techniques to forecast minimum and maximum temperatures for the Dhaka city station. The following most popular soft computing techniques are chosen, which composed of fuzzy logic, neural network and genetic algorithm:

(a) Fuzzy neuro model
(b) Neuro genetic algorithm model

All of this combination is widely used in prediction of time series data (Nayak et al. (2004), Dounis et al. (1997), Khan et al. (2008), Lin (2004)). To compare results, beside these techniques, we have selected a popular statistical technique, namely autoregressive integrated moving average time series technique.

A brief description of the above popular selected models is described below:

3.1 FUZZY NEURO MODEL

The basic concept comprises the neural approach, fuzzy theory such as fuzzy set, membership functions and fuzzy if-then inference rules. That means it is a combination of two intelligence systems: (i) fuzzy inference system and (ii) neural network system, where neural network learning algorithm is used to determine parameters of fuzzy inference system. It is the first integrated hybrid neuro-fuzzy model, introduced by Jang (1993) and is referred to literature as adaptive network based fuzzy inference system (ANFIS). This system has 5 layers: (i) 1 input layer (ii) 3 hidden layers that represents mfs and fuzzy rules and (iii) 1 output layer. See Jang (1993) for its architecture. First, it uses the training data set to build the fuzzy system in which membership functions are adjusted using the back-propagation algorithm, allowing that the system learns with the data that it is modeling. The membership function patterns used for the input series are of triangular shape, trapezoidal shape, Gaussian shape, sigmoidal shape and others. The fuzzy inputs with their associated membership functions form inputs to the neural network, which processed through a transfer functions (such as hard limit, linear, pureline, transig, logsigmoid, sigmoid) at the nodes of different layers of the network to obtain output. The learning algorithm of ANFIS is a hybrid algorithm, which combines the gradient descent (GD) method and the least square estimation (LSE) for an effective search of parameters. ANFIS uses a two pass of learning algorithm to reduce error: (i) forward pass and (ii) backward pass. The hidden layer is computed by the GD method of the feedback structure and the final output is estimated by the LSE method (details, see Jang (1993)).

3.2 NEURO GENETIC ALGORITHM MODEL

We used GA based neural network model. The steps are as follows:

(i) Construct first artificial neural network architecture by error and trial method.
(ii) Extract weights for the above network by implementing genetic algorithm i.e. construct a back-propagation network with GA (ANN-GA).
(iii) Train the ANN-GA network with different parameter values of population.
(iv) Find the best parameter value from the selected population parameters values to forecast temperatures.

A brief description of ANN and GA methodologies is given below.

3.2.1 ARTIFICIAL NEURAL NETWORK MODEL

It is introduced by Culloch (1943) consists the following processing functions: (i) Receiving inputs (ii) Assigning appropriate weight coefficients of inputs (iii) Calculating weighted sum of inputs (iv) Comparing this sum with some threshold and finally (v) Determining an appropriate output value. An ANN structure has 1 input layer, two hidden layers (with sufficient no. of neurons) and 1 output layer. See Culloch (1943) for its architecture. The training algorithm is the standard back-propagation, which uses the GD technique to minimize error. During training, each estimated temperature is compared with the actual temperature and calculates error at the output layer. The backward pass is the error back-propagation and adjustments of weights. Thus, the network is adjusted based on a comparison of output and the target until the network output matches the target. When the training process is completed, then the network with adjusted estimated parameters is used to test a set of data, which is different from the training set of data. For details, see Culloch (1943) and Banik et al. (2012).

3.2.2 GENETIC ALGORITHM MODEL

This technique is proposed by Holland (1975). It is a computerized search and optimization algorithm based on the mechanics of natural genetics and natural selection. It operates on a population of individuals which represent solution for a given problem.

3.2.2.1 GENETIC TERMS

It involves the following terms:

Chromosomes – Population characteristics.

Population- A set of solutions represented by chromosomes.

Fitness function - It measures the performance of the system. The fitness function to be evolved is problem dependent. For prediction and estimation problem, the function will be root mean square error, coefficient of determination etc.

3.2.2.2 GENETIC OPERATORS

It consists of three operators:

Reproduction – It is also known as selection operator is used to select the best chromosomes for parents from population.

Crossover - Basic operator for producing new (improved) chromosomes is known as crossover (a version of artificial mating). It produces offspring that have some parts of both parents genetic material. Offspring are produced using the intermediate crossover method, because this is a method proposed to recombine of parents with real valued chromosomes.

Mutation - Offspring are mutated after being produced crossover offspring and this GA operator increases the chance that the algorithm will generate better fittest MSE (for example) than the GA crossover operator. For details of the GA procedures, see Holland (1975) and Banik et al. (2009).

Thus, we developed a GA based ANN system, which is a neuro-genetic hybrid approach, where GA is used to determine the weights of a multilayer network with the back propagation learning.

3.3 AUTOREGRESSIVE INTEGRATED MOVING AVERAGE MODEL

In statistics, traditionally, a time series forecasting problem is tackled using the technique Autoregressive Integrated Moving Average (ARIMA) model introduced by Box and Jenkins (1976). We have chosen this method, because it is a very popular statistical method, which is widely used to forecast time series data in time series literature. General form of an ARIMA(p,d,q) can be written as follows, where p is the autoregressive order, d is the integration order and q is the moving average order:

$$\mathrm{Temp}_t = \mathrm{constant} + \sum_{i=1}^{p} a_i \mathrm{Temp}_{t-i} + \sum_{j=1}^{q} b_j e_{t-j} + e_t, \quad t = 1,2,\ldots, n$$

where Temp_t is the observed temperatures, a_i denotes autoregressive coefficients, b_j denotes moving average coefficients and e_t is a white noise disturbances term.

In this paper, an effort has been made to predict temperatures for the Dhaka city applying methods (3.1)-(3.3). Finally, based on the error analysis, suitable models have been recommended to predict temperatures for the Dhaka city.

The functional patterns for forecasting models of MinTem and MaxTem variables are as follows:

$$\mathrm{MinTem}_t = f(\text{lag values of } \mathrm{MinTem}_{t-i}), \quad i = 1,2,\ldots p$$

$$\mathrm{MaxTem}_t = f(\text{lag values of } \mathrm{MaxTem}_{t-i}), \quad i = 1,2,\ldots p$$

where p is the lag order chosen by the selected forecasting models. Our target is to estimate the above models parameters using the techniques of ANFIS, GA-ANN and ARIMA.

4. EVALUATION CRITERIA AND EXPERIMENTAL RESULTS

4.1 EVALUATION CRITERIA

The comparison and the evaluation of the selected models are done according to their predictions using the following statistical estimators:

(i) Root mean square error (RMSE)

(ii) Coefficient of correlation (ρ)

(iii) Coefficient of determination (R^2)

These are defined as follows:

$$\mathrm{RMSE} = \sqrt{\frac{\sum_{i=1}^{n}(O_i - P_i)^2}{n}},$$

$$\rho = \frac{\sum_{i=1}^{n}(O_i - O_{AVG})(P_i - P_{AVG})}{\sqrt{\sum_{i=1}^{n}(O_i - O_{AVG})^2}\sqrt{\sum_{i=1}^{n}(P_i - P_{AVG})^2}}$$

$$R^2 = \left[\frac{\sum_{i=1}^{n}(O_i - O_{AVG})(P_i - P_{AVG})}{\sqrt{\sum_{i=1}^{n}(O_i - O_{AVG})^2}\sqrt{\sum_{i=1}^{n}(P_i - P_{AVG})^2}}\right]^2$$

where n = Total no of observations, O_i = observed temperature, P_i = predicted temperature, O_{AVG} = average observed temperature and P_{AVG} = average predicted temperature. RMSE are used to measure the accuracy of prediction through representing the degree of scatter and a smallest value of RMSE indicates higher accuracy in forecasting. Correlation coefficient ρ represents the strength of relation (match between observed and predicted temperatures). R^2 is a measure of the accuracy of prediction of the trained network models. Higher ρ and R^2 values indicate better prediction.

4.2. RESULT ANALYSIS

For development of all models for forecasting Dhaka temperatures, MATLAB programming codes are used. The first 50% data are used as the training period and the rest 50% as the testing period. To reduce error, an error and trial approach for MinTem and MaxTem variables is used to find the computational settings for each of selected techniques, which are reported in Table 3. Initially an ANN model is developed and then it is integrated with fuzzy logic to develop an ANFIS model. Further the ANN weights are optimized by genetic algorithm to develop a GA-ANN model. For the accuracy of the ARIMA models, autocorrelation function and partial autocorrelation correlograms are examined (figures are available on request) and the model is obtained is ARIMA(3,1,2) for both MinTem and MaxTem variables. The estimated equations obtained by ARIMA(3,1,2) are as follows:

$$MinTem_t = 0.3693 + 0.1190 MinTem_{t-1} - 0.8429 MinTem_{t-2} + 0.1186 MinTem_{t-3} + 0.1197 e_{t-1} - 0.6040 e_{t-2}, t = 1,2,,...,n$$

$$MaxTem_t = 3.2759 + 0.1168 MaxTem_{t-1} + 0.0589 MaxTem_{t-2} - 0.1210 MaxTem_{t-3} - 0.5961 e_{t-1} + 0.1139 e_{t-2}, t = 1,2,,...,n$$

The performance measures used to evaluate the models are RMSE, ρ and R^2. Results are tabulated in Tables 4-5. The graphical comparison between observed and 3 models predicted temperatures are shown in Figures 2 to 3.

It has been observed that for the MinTem series and for the training data, RMSE obtained from various models lie in the range of 1.8333-2.8300 with the GA-ANN model performing the best with RMSE 1.8333 (i.e. good match between actual and predicted temperatures), followed by ANFIS with RMSE 2.7773. Similarly, it is observed that the GA-ANN predicted temperature matches well with the observed temperature showing a high value of 0.9633 followed by the ANFIS and the ARIMA with R^2 values of 0.9337 and 0.8933 respectively.

For testing data, the RMSE obtained from various model lie in the range of 1.7237-3.8229 with the GA-ANN model performing the best with RMSE 1.7237, followed by ANFIS with RMSE 3.7800. Similarly, we observed that the GA-ANN predicted temperature matches well with the observed temperature showing a high value of 0.9943 followed by the ANFIS and the ARIMA with R^2 values of 0.9454 and 0.9071 respectively.

TABLE 3: ANFIS, GA-ANN AND ARIMA ARCHITECTURE PARAMETERS FOR TEMPERATURE FORECASTING MODELS

ANFIS		GA-ANN		ARIMA	
No. of Inputs	6	No. of input neurons	10	No. of AR coefficients	3
No. of MF	3	No. of Hidden neurons	6	Integration order	1
MF type	Gaussian	No.of hidden layers	2	No. of MA coefficients	2
Transfer function of hidden layer	Sigmoid	Learning rate	0.01		
Transfer function of output layer	Linear	Tansfer function of hidden layer	Sigmoid		
Training algorithm	Hybrid	Transfer function of output layer	Linear		
Training goal	0.01	Momentum factor	0.30		
		Training algorithm	Back-propagation		
		Training goal	0.01		
		Population	1000		
		Generation	200		
		Selection function	Roulette		
		Crossover rate	0.90		
		Mutation rate	Gaussian		

TABLE 4: PERFORMANCE MEASURES OF SELECTED MODELS FOR TRAINING DATA

Performance Measures	ANFIS	GA-ANN	ARIMA	ANFIS	GA-ANN	ARIMA
	MinTem			MaxTem		
RMSE	2.7773	1.8333	2.8300	1.89	1.5945	1.9200
ρ	0.9662	0.9814	0.9451	0.9930	0.9964	0.9778
R^2	0.9337	0.9633	0.8933	0.9862	0.9929	0.9561

TABLE 5: PERFORMANCE MEASURES OF SELECTED MODELS FOR TESTING DATA

Performance Measures	ANFIS	GA-ANN	ARIMA	ANFIS	GA-ANN	ARIMA
	MinTem			MaxTem		
RMSE	3.7800	1.7237	3.8229	5.3200	4.4514	5.8900
ρ	0.9723	0.9971	0.9524	0.9241	0.9461	0.9193
R^2	0.9454	0.9943	0.9071	0.8541	0.8952	0.8452

FIGURE 2: ACTUAL AND PREDICTED MINIMUM TEMPERATURES

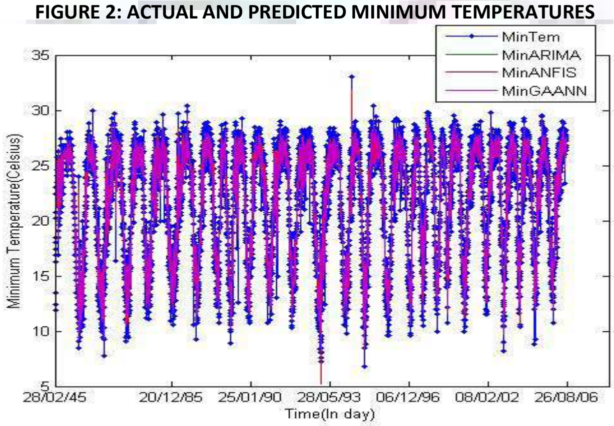


FIGURE 2A: ACTUAL AND PREDICTED MINIMUM TEMPERATURES FOR SOME PERIODS

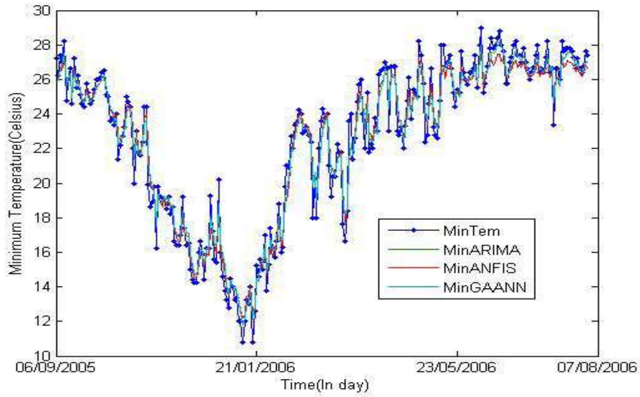


FIGURE 3: ACTUAL AND PREDICTED MAXIMUM TEMPERATURES

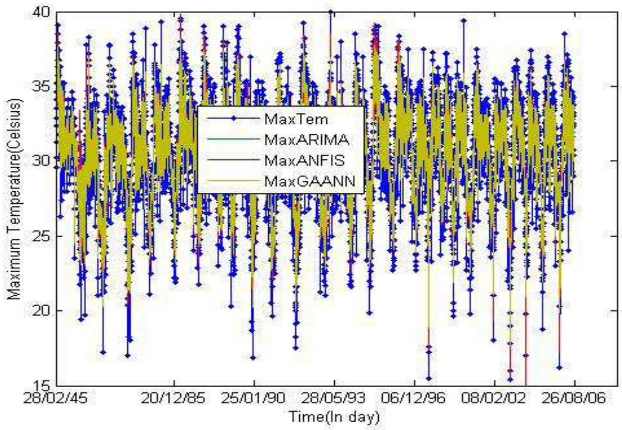
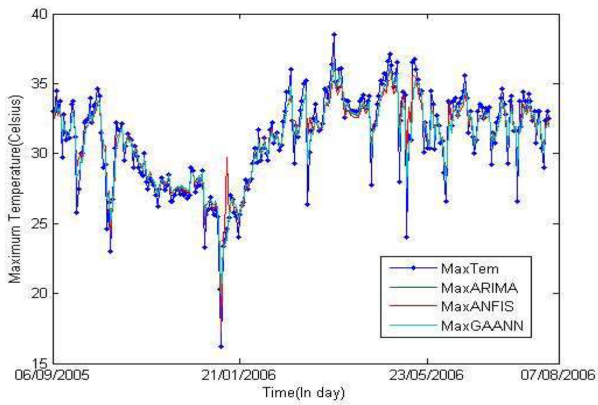


FIGURE 3A: ACTUAL AND PREDICTED MAXIMUM TEMPERATURES FOR SOME PERIODS



As also can be understood from Tables IV-V, compared to the ARIMA and ANFIS, the GA-ANN for the MaxTem series due to RMSE, ρ and R^2 values, can more efficiently capture dynamic behavior of the weather temperature.

In order to see how well our considered models fitted to the actual MinTem and MaxTem, Figure 2 and Figure 3 added, where three selected forecasting models performances are shown with observed temperatures. To avoid the clumsiness of the figures that means for better understanding, we have added Figure 2a and Figure 3a. The graphical comparison between the observed and considered predicted models temperatures follow the trend of the observed graph. However, it is observed that GA-ANN predicted graph matches well as compare to the ANFIS and ARIMA predicted graphs.

5. CONCLUSION

Using soft computing methodologies, this paper modeled important meteorological parameter namely minimum and maximum temperatures for the Dhaka city, which affects our daily lives and decisions in many ways. We developed an adaptive neural fuzzy inference model and a genetic algorithm based neural network model to predict Dhaka city temperatures. To compare performances of the above two soft computing methodologies, a popular statistical forecasting technique namely autoregressive moving average time series model is used. Initially an artificial neural network model is developed and it is then integrated with fuzzy logic to develop an adaptive neural fuzzy inference model. Further the artificial neural network weights are optimized by genetic algorithm to develop a genetic algorithm based on neural network model. The comparison and evaluation for the considered systems are done according to their predictions using several statistical estimators, namely root mean square error, correlation coefficient and coefficient of determination. Our findings suggest that genetic algorithm based neural network model predicts temperature with maximum accuracy as compared to the adaptive neural fuzzy inference model and the selected time series model. The adaptive neural fuzzy inference model and the autoregressive moving average model performances are not same, but the adaptive neural fuzzy inference model predicts temperature better than the autoregressive moving average model. The proposed models in this paper could also be used to predict other important meteorological variables namely humidity, wind speed etc. which is also very important for many reasons. This is left for future research.

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