Research Article

Monthly Temperature Prediction using ANNs and ANFIS (Case Study: Tehran City)

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Abstract

Temperature is one of the most important parameters among climate parameters. Prediction of monthly temperature is very important in water resources management, agriculture, and many other fields. For this purpose, different empirical or semi-empirical models and time series analysis are used. Recently, new intelligent methods such as ANNs and ANFIS have largely been applied in all scientific and engineering fields. In this research, the two intelligent models including the ANNs and ANFIS for monthly minimum, maximum, and mean temperatures estimation were developed in synoptic station of Tehran, Iran. Minimum, maximum, and mean data were divided to three parts including training, testing, and checking data for a month ago, two months ago, and three months ago. After introducing the data to each model, the training,

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testing, and checking of models were done separately and results were analyzed. Results showed
that the ANNs are better that ANFIS for predicting of temperatures.

**Keywords:** Temperature estimation, ANNs, ANFIS, Mehrabad

1. Introduction

Temperature is one of the most important parameters among climate parameters. Prediction of
monthly temperature is very important in water resources management, agriculture, and many
other fields. Damage to plants and animals caused by extreme temperature is a serious concern
for agricultural producers. Different empirical or semi-empirical models and time series analysis
are used for the estimation of air temperature. In recent years, new intelligent methods have
largely been applied in all scientific and engineering fields [1,2]. The application of Artificial
Neural Network (ANN) models is quickly increasing due to easy application and high accuracy
of these models to approximate complex nonlinear mathematical equations [3,4]. Also, Adaptive
Nero Fuzzy Inference System (ANFIS) has been used to analyze the non-linear phenomena and
to estimate the relation between input-output in systems consisting of various parameters. A
number of researches in agro hydrological fields have been carried out by using Adaptive Nero
Fuzzy Inference System. Nayak et al used ANFIS models for short-term stream flow and flood
forecasting [5,6]. Kisi investigated the accuracy of ANFIS technique in daily evaporation
modeling [7]. Kisi and Ozturk used this technique for the estimation of the evapotranspiration
to predict the water need rate of the reference crop [8]. Smith et al explored the application of
ANNs for the prediction of air temperature during the entire year based on near real-time data
[9]. The goal of the research presented herein was to develop two intelligent models including
the ANN and ANFIS for monthly minimum, maximum, and mean temperature estimation in the
synoptic station of Tehran, Iran.

2. Artificial Neural Networks (ANN)

Artificial neural networks (ANN) are intelligent systems that have the capacity to learn,
memorize and create relationships among data [10]. An ANN is composed of simple calculation
elements, called neurons or nodes which are operating in parallel [11]. A typical neural network
consists of an input, a hidden (or intermediate) and output layer. Other components include a
neuron, weight and a transfer function. In the hidden layer, the number of neurons was defined
by the smallest error criterion and the constant effective number of parameters as well. The
nodes in the output layer represent the variables to be predicted. In a way, ANNs mimic the
learning process of a human brain and therefore do not need characteristic information about the
system; instead, they learn the relationship between input parameters and the output variables by studying previously recorded data [12]. On the other word, Training of a neural network is basically the process to find a set of optimum weights of the network. In this work, the training of the neural model was carried out by using the “trainer” function of the Neural Network Toolbox (MATLAB R2009a), which consists of the Levenberg-Marquardt Bayesian Regularization algorithm. Figure 1 shows a typical neuron in a neural network. An input $x_j$ is transmitted through a connection which multiplies its strength by a weight $w_{ij}$ to give a product $x_jw_{ij}$. This product is an argument to a transfer function $f$ which yields an output $y_i$ represented by Eq. below. Such iterative makes up the training process [13]:

$$y_i = f\left(\sum_{j=1}^{n} x_jw_{ij}\right)$$  \hspace{1cm} (1)

Where $i$ is an index of neuron in the hidden layer and $j$ is an index of an input to the neural network. The nature and complexity of the phenomenon to be trained will detect the structure of the neural network in terms of the number of hidden layers, number of neurons in these layers, training algorithm and the transfer function used. In retrospect, artificial neural networks are ideal for modeling non-linear, dynamic, noise-ridden and complex systems. In particular, ANN is good for tasks involving incomplete data sets, fuzzy or incomplete information and for highly complex and ill-defined problems.

3. Adaptive Nero-Fuzzy Inference System (ANFIS)

The ANFIS is a hybrid model in which the nodes in the different layers of the network handle fuzzy parameters, representing a useful neural network approach for the solution of function approximation problems. Data driven procedures for the synthesis of ANFIS networks are typically based on clustering a training set of numerical samples of the unknown function to be approximated. Each layer in the network corresponds to a part of the fuzzy inference system (FIS) called: input fuzzification, rule inference and fire strength computation, and output defuzzification. Using a given input/output data set, ANFIS constructs an FIS whose membership function parameters are adjusted using a back propagation algorithm either alone or in combination with a least-squares type of method. The learning technique allows the fuzzy systems to learn input/output mapping from the data that are being modeled. The adjustment of membership function parameters is achieved by gradient vector, which provides a measure of how well the fuzzy inference system is modeling the input/output data. Once the gradient vector is obtained, any of the several optimization routines could be applied in order to adjust the parameters so as to reduce mean squared error between actual and desired outputs [14].
advantage of this kind of representation is that the FIS parameters are encoded as weights in the neural network and, thus, can be optimized via powerful well known neural net learning methods. This model is mostly suited to the modeling of nonlinear systems [15,16]. In this work, the training of the neuron-fuzzy estimator was performed using the ANFIS toolbox of MATLAB R2009a.

4. Study Area and Available Data

Minimum, maximum, and mean temperature of Mehrabad synoptic station of Tehran, Iran, was used in this study. This station is at 35° 41´ N, 51° 19´ E with elevation of 1190 meters above sea level. Fig. 2 shows the geographical location of the study area. Some statistical parameters of the temperature at Mehrabad station is given in Table 1.

<table>
<thead>
<tr>
<th>Table 1. Some statistical parameters of the temperature (°C) data used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statistical parameter</td>
</tr>
<tr>
<td>Number</td>
</tr>
<tr>
<td>Average (°C)</td>
</tr>
<tr>
<td>Max (°C)</td>
</tr>
<tr>
<td>Min (°C)</td>
</tr>
<tr>
<td>Variance (°C²)</td>
</tr>
<tr>
<td>Skewness (°C²)</td>
</tr>
<tr>
<td>Standard Deviation (°C²)</td>
</tr>
</tbody>
</table>

5. Evaluation Criteria

Squared correlation coefficient (R) and Root Mean Squared Error (RMSE) were used for evaluating the model performance, which are defined as Eq. below:

\[
R^2 = \left( \frac{\sum_{i=1}^{N} (T_i^O - \bar{T}^O)(T_i^E - \bar{T}^E)}{\sqrt{\sum_{i=1}^{N} (T_i^O - \bar{T}^O)^2 \cdot \sum_{i=1}^{N} (T_i^E - \bar{T}^E)^2}} \right)^2
\]

\[
RMSE = \sqrt{\frac{\sum_{i=1}^{N} (T_i^E - \bar{T}^O)^2}{N}}
\]
In which, $T^o_i$ is the observed value at the ith time step, $T^e_i$ is the corresponding estimated value, $\bar{T}^o$ and $\bar{T}^e$ are the mean values of the observed and the estimated air temperature, respectively and N is the number of data.

6. Results and Discussion

The minimum, maximum, and mean temperature values of Mehrabad-Tehran synoptic station for a period of 55 years were used in this research. For predicting the temperature ANNs and ANFIS models were used. For this purpose, the data were divided in three parts in order to train, test, and check the model. Different percentage of training, testing, and checking data were investigated and finally the best combination of data were found. In ANNs model 75% data were used for training, 15% for validating, and 15% for testing. Number of data are 657 which 457, 100, and 100 of them were used for training, testing, and checking, respectively, in ANFIS model. For each model, the data of three month ago, two month ago, and a month ago were used. The results of models were analyzed in Excel, and Regression (R) and RMSE calculated for minimum, maximum, and mean temperature. Results are shown in Table 2. In this Table Tmax, Tmin, Tmean are the maximum, minimum, and mean temperature, respectively, and $T_{i-1}$, $T_{i-2}$, $T_{i-3}$ are a month ago, two month ago, and three month ago temperature for maximum, minimum, and mean temperature, respectively. Generally, the minimum value of R in each temperature in a month ago is minimum and in three months ago is maximum for two models. These variations for RMSE are invers and in a month ago RMSE is maximum and in three months ago is minimum. The maximum and minimum values of R for ANNs model are 0.979 and 0.847 respectively, while these values for ANFIS model are 0.974 and 0.844 respectively. As shown the values of R for ANNs is lower than that of for ANFIS. For minimum temperature, the value of R for a month ago and two months ago is equal for ANNs and ANFIS models, however, the RMSE in ANFIS is lower than that of in ANNs for a month ago temperature. For three months ago both R and RMSE in ANNs is lower than those of in ANFIS. For maximum and mean temperatures, the values of R in ANFIS is lower than those of in ANNs and the values of RMSE in ANNs is lower than those of in ANFIS. In ANNs model, predicting of temperatures using three months ago data have high R and low RMSE. Considering Table 2 some other comparisons could be done for models.
Correlation equations between observed and estimated data are given in Table 3 in which O is for observed data and E is for estimated data.

Table 3. Correlation equation between observed and estimated data

<table>
<thead>
<tr>
<th>Model</th>
<th>Tmax</th>
<th>Tmin</th>
<th>Tmean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>E = 0.7609O + 5.7807</td>
<td>E = 0.7065O + 3.561</td>
<td>E = 0.7731O + 3.7395</td>
</tr>
<tr>
<td>ANN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$T_{i-1}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$T_{i-1}, T_{i-2}$</td>
<td>E = 0.9404O + 1.3578</td>
<td>E = 0.9492O + 0.5824</td>
<td>E = 0.9412O + 1.0846</td>
</tr>
<tr>
<td>$T_{i-1}, T_{i-2}, T_{i-3}$</td>
<td>E = 0.9515O + 1.1833</td>
<td>E = 0.9504O + 0.8289</td>
<td>E = 0.9582O + 0.7652</td>
</tr>
<tr>
<td>ANFIS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$T_{i-1}$</td>
<td>E = 0.7113O + 6.545</td>
<td>E = 0.7185O + 3.2654</td>
<td>E = 0.7167O + 4.8536</td>
</tr>
<tr>
<td>$T_{i-1}, T_{i-2}$</td>
<td>E = 0.932O + 1.4706</td>
<td>E = 0.9463O + 0.4699</td>
<td>E = 0.9202O + 1.2527</td>
</tr>
<tr>
<td>$T_{i-1}, T_{i-2}, T_{i-3}$</td>
<td>E = 0.9506O + 1.0458</td>
<td>E = 0.9462O + 0.358</td>
<td>E = 0.9544O + 0.5966</td>
</tr>
</tbody>
</table>

Considering the values of R and RMSE, it could be concluded that the ANNs model have the better results than ANFIS model and the extracted equations of this model could be used for predicting of minimum, maximum, and mean temperatures with high accuracy. In addition predicting accuracy using three month ago data have better results.

7. Conclusion

Modeling and estimation of temperature is important in agricultural meteorology, scheduling, design and management of water resources. In this research, the two intelligent models including
the ANNs and ANFIS for Monthly temperature estimation were developed in synoptic station of Tehran, Iran. Minimum, maximum, and mean data were divided to three parts including training, testing, and checking data for a month ago, two month ago, and three month ago. After introducing the data to each model, the training, testing, and checking of models were done separately and results were analyzed using regression factor (R) and RMSE. Considering the values of R and RMSE, the ANNs model have the better results than ANFIS model, in addition in ANNs model, predicting accuracy using three month ago data have better results.

References


