Weather Temperature Forecasting Using Artificial Neural Network

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Abstract

Weather forecasts and warnings are the most important services provided by the meteorological profession. Forecasts are used by government and industry to protect life and property and to improve the efficiency of operations, and by individuals to plan a wide range of daily activities. Many searches have been made in weather forecasting using Artificial Neural Network (ANN) output one weather temperature degree, which give a little indicator about the weather temperature.

In this paper, two weather temperatures have been forecasted using Artificial Neural Network (ANN). The design of the ANN based on two previous weather temperatures degrees (high and low), as well as, the increasing and decreasing weather temperature degree according to thermal retention. The ANN design has been applied for Baghdad city, the capital of Iraq. The training and testing used meteorological data for three years (2007-2010).

Keywords—Artificial neural networks, Forecasting, Weather, feed-forward with back propagation.

الخلاصة

تنبؤات وإنذارات الطقس من أكثر الخدمات المهمة المُقدمة من قِبل مُختصي الإرصاد الجوي. الحكومة والصناعة استخدمت التنبؤات للحفاظ على الحياة والممتلكات ولتحسين كفاءة العمليات، وكذلك الأفراد استخدمت التنبؤات لتخطيط مدى واسع من الفعاليات اليومية. بحوث عديدة قد وضعت لتنبؤ الطقس استخدمت الشبكة العصبية الصناعية، والتي اخرجت حرارة طقس واحدة، وبذلك اعطت دلالة قليلة حول حرارة الطقس.

في هذا البحث، درجتان للطقس قد تم التنبؤ بها باستخدام الشبكة العصبية الصناعية. إن التصميم للشبكة العصبية الصناعية قد اعتمدت على درجتان سابقتان لحرارة الطقس (العُليا والدُنيا)، وكذلك زيادة ونقصان درجة حرارة الجو طبقاً للإحتباس الحراري. إن تصميم الشبكة العصبية قد تم تطبيقهُ على مدينة بغداد، عاصمة العراق. التدريبات والفحوصات استخدمت بيانات الإرصاد الجوي لثلاث سنوات (2007-2010).

1. Introduction:

Weather forecasting is the application of science and technology to predict the state of the atmosphere for a future time and a given location. Human kind has attempted to predict the weather since ancient times. Today, weather forecasts are made by collecting quantitative data about the current state of the atmosphere and using scientific understanding of atmospheric processes to project how the atmosphere will evolve. For millennia people have tried to forecast the weather. In 650 BC, the Babylonians predicted the weather from cloud patterns as well as astrology. In about 340 BC, Aristotle described weather patterns in Meteorological [1]. Later, Theophrastus compiled a book on weather forecasting, called the Book of Signs [2]. Chinese weather prediction lore extends at least as far back as 300 BC [3], which was also around the same time ancient the Indian astronomers developed weather-prediction methods [4]. In 904 AD, Ibn Wahshiyya's Nabatean Agriculture discussed the weather forecasting of atmospheric changes and signs from the planetary astral alterations; signs of rain based on observation of the lunar phases; and weather forecasts based on the movement of winds [5]. Ancient weather forecasting methods usually relied on observed patterns of events, also termed pattern recognition. For example, it might be observed that if the sunset was particularly red, the following day often brought fair weather. This experience accumulated over the generations to produce weather lore. However, not all of these predictions prove reliable, and many of them have since been found not to stand up to rigorous statistical testing [6]. It was not until the invention of the electric telegraph in 1835 that the modern age of weather forecasting began [7]. Before this time, it was not widely practicable to transport information about the current state of the weather any faster than a steam train (and the train also was a very new technology at that time).

By the late 1840s, the telegraph allowed reports of weather conditions from a wide area to be received almost instantaneously [8], allowing forecasts to be made from knowledge of weather conditions further upwind. The two men most credited with the birth of forecasting as a science were Francis Beaufort (remembered chiefly for the Beaufort scale) and his protégé Robert Fitzroy (developer of the Fitzroy barometer). Both were influential men in British naval and governmental circles, and though ridiculed in the press at the time, their work gained scientific credence, was accepted by the Royal Navy, and formed the basis for all of today's weather forecasting knowledge [9]. To convey information accurately, it became necessary to have a standard vocabulary describing clouds; this was achieved by means of a series of classifications and, in the 1890s, by pictorial cloud atlases. Great progress was made in the science of meteorology during the 20th century. The possibility of numerical weather prediction was proposed by Lewis Fry Richardson in 1922 [10], though computers did not exist to complete the vast number of calculations required to produce a forecast before the event had occurred. Practical use of numerical weather prediction began in 1955 [11], spurred by the development of programmable electronic computers.

In the United States, the first public radio forecasts were made in 1925 by Edward B. "E.B." Rideout, on WEEI, the Edison Electric Illuminating station in Boston [12]. Rideout came from the U.S. Weather Bureau, as did WBZ weather forecaster G. Harold Noyes in 1931. Television forecasts followed with Jimmie Fidler in Cincinnati in 1940 or 1947 on the DuMont Television Network [12][13]. The Weather Channel is a 24-hour cable network that began broadcasting in May 1982.

2. Numerical weather prediction:

Numerical weather prediction uses current weather conditions as input into mathematical models of the atmosphere to predict the weather. Although the first efforts to accomplish this were done in the 1920s, it wasn't until the advent of the computer and computer simulation that it was feasible to do in real-time. Manipulating the huge datasets and performing the complex calculations necessary to do this on a resolution fine enough to make the results useful requires the use of some of the most powerful supercomputers in the world. A number of forecast models, both global and regional in scale, are run to help create forecasts for nations worldwide. Use of model ensemble forecasts helps to define the forecast uncertainty and extend weather forecasting farther into the future than would otherwise be possible. British mathematician Lewis Fry Richardson first proposed numerical weather prediction in 1922. Richardson attempted to perform a numerical forecast but it was not successful. The first successful numerical prediction was performed in 1950 by a team composed of the American meteorologists Jule Charney, Philip Thompson, Larry Gates, and Norwegian meteorologist Ragnar Fjörtoft and applied mathematician John von Neumann, using the ENIAC digital computer.

They used a simplified form of atmospheric dynamics based on the barotropic vorticity equation. This simplification greatly reduced demands on computer time and memory, so that the computations could be performed on the relatively primitive computers available at the time. When news of the first weather forecast by ENIAC was received by Richardson in 1950, he responded that the results were an "enormous scientific advance." The first calculations for a 24 hour forecast took ENIAC nearly 24 hours to produce [14]. Later models used more complete equations for atmospheric dynamics and thermodynamics. Operational numerical weather prediction (i.e., routine predictions for practical use) began in 1955 under a joint project by the U.S. Air Force, Navy, and Weather Bureau [15].

3. Artificial Neural Network (ANN):

An artificial neural network (ANN), usually called neural network (NN), is a mathematical model or computational model that is inspired by the structure and/or functional aspects of biological neural networks. A neural network consists of an interconnected group of artificial neurons, and it processes information using a connectionist approach to computation.

In most cases an ANN is an adaptive system that changes its structure based on external or internal information that flows through the network during the learning phase. Modern neural networks are non-linear statistical data modeling tools. They are usually used to model complex relationships between inputs and outputs or to find patterns in data [16].

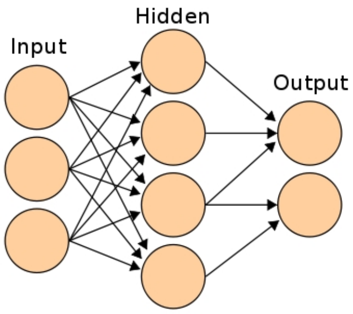

Figure 1: An artificial neural network is an interconnected group of nodes.

Neural networks have seen an explosion of interest over the last few years, and are being successfully applied across an extraordinary range of problem domains, in areas as diverse as finance medicine, engineering, geology and physics. Indeed, anywhere that there are problems of prediction, classification or control, neural networks are being introduced. Neural networks could be define as an interconnected of simple processing element whose functionality is based on the biological neuron. Biological neuron is a unique piece of equipment that carries information or a bit of knowledge and transfers to other neuron in the chain of networks. Artificial neuron imitates these functions and their unique process of learning [16].

4. Previous ANN work:

Mohsen Hayati, and Zahra Mohebi design of short-term temperature forecasting (STTF) Systems for Kermanshah city, west of Iran was explored. The neural networks named Multi-Layer Perceptron (MLP) to model STTF systems are used. The study based on MLP was trained and tested using ten years (1996-2006) meteorological data. The optimal structures for developed MLP neural network for obtaining minimum prediction error are shown in Table 1.

Table 1: MLP Structure.

Layer	No. of neurons	Activation function
Input layer	7	---
Hidden layer	6	tangent sigmoid
Output layer	1	Pure linear
No. of Neurons	14	One day ahead
No. of Epochs	2000	

The result of MLP network model has been used for one day ahead temperature forecast in the Kermanshah, Iran [17]. And output one temperature, which give a little indicator about weather temperature.

5. Suggested ANN work:

The suggested ANN design has been implemented based on feed-forward with back-propagation. The suggested design consists of one input layer, two hidden layer and one output layer, as shown in figure 2.

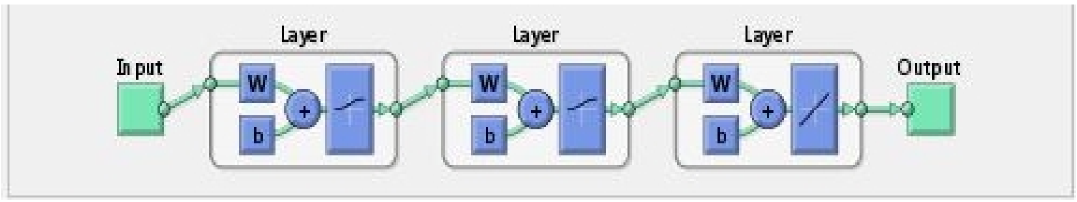

Figure 2: The suggested ANN design.

The number of input neurons depend on the input (low and high) temperatures, thus we have two input neurons. As the same manner, the two output neurons required to produce two temperatures forecasted. The hidden layers which represent ANN memory, after many training and testing, two hidden layer has been selected, as shown in the following table:

Table 2: Suggested ANN Structure.

Layer	No. of neurons	Activation function
Input layer	2	---
Hidden layer 1	4	Log-sigmoid
Hidden layer 2	2	Log-sigmoid
Output layer	2	Pure linear
No. of Neurons	10	One month ahead
No. of Epochs	Between 6 to 241	

The suggested ANN network model has been used for one month ahead temperatures forecasting in Baghdad, Iraq. This ANN outputs two weather temperature forecasting, average high and low. The inputs (low, high temperature degrees) on ANN have been taken from metrology data, the targets of the suggest ANN have been calculated according to the following:

Target 1 = Low Temp. ± ther. Deg. …(1).

Target 2 = High Temp. ± ther. Deg. …(2).

Where:

Low Temp. the average of low temperature degree of previous year.

High Temp. the average of high temperature degree of previous year.

Ther. Deg. The temperature degree that increasing or decreasing according to thermal retention.

The suggested ANN has been described in the following schema, which is consisted mainly from four parts, input data files, main form, ANN system, and output data files.

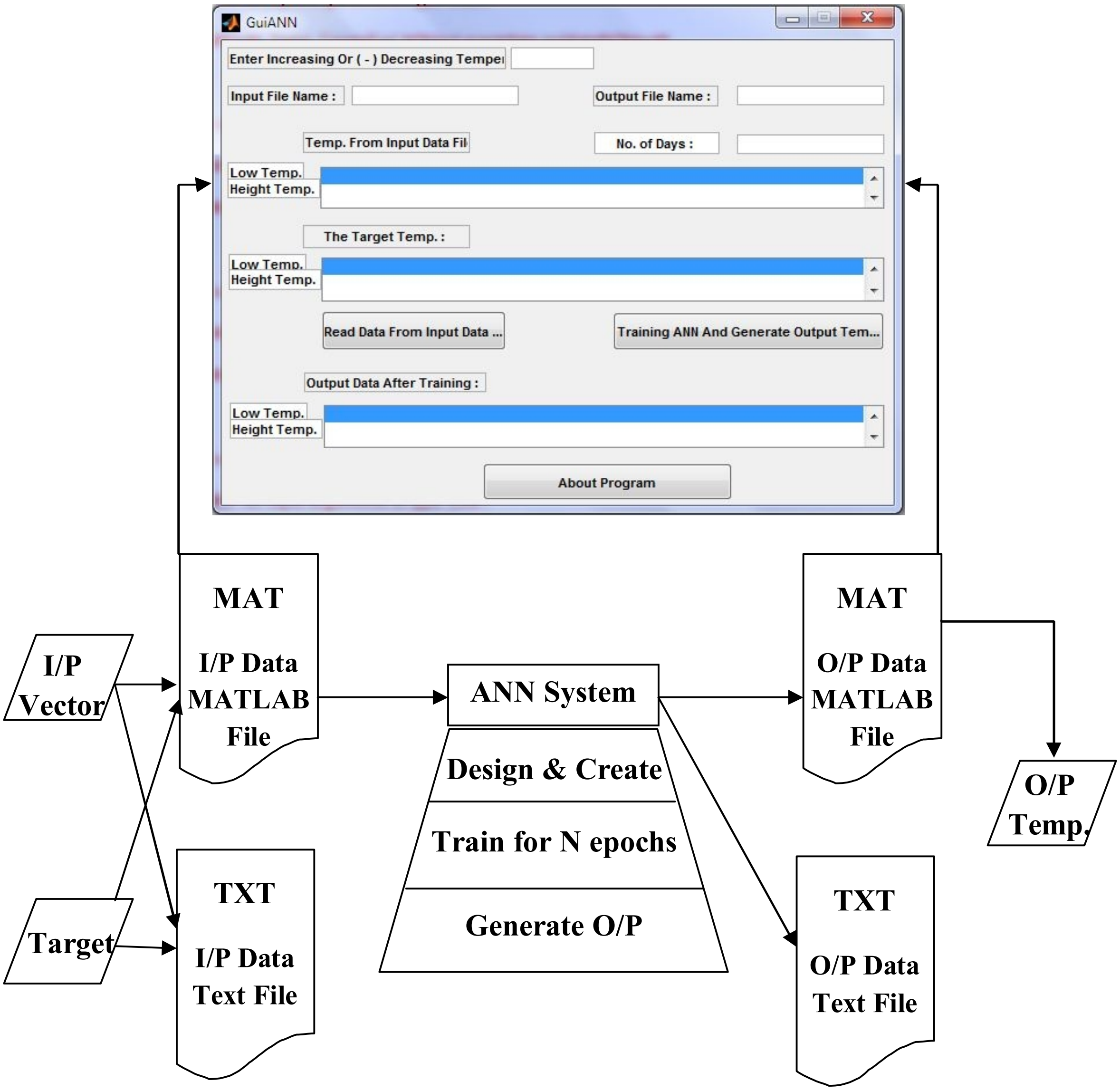

Figure 3: Suggested ANN schema.

6. Result, conclusion and future work:

Two weather temperatures have been forecasted for twelve months. Three months have been selected to discuss its results. The first month that has been trained and test is January, the second selected month is March which represents summer solstice. The third month that has been selected is September which represents winter solstice. The performance of the suggested ANN is measured by mean square error, for the first month January, a comparison have been made between sets of training, validation, test and best. The performance has been reached to best validation at epoch (11), as shown in the figure 4.

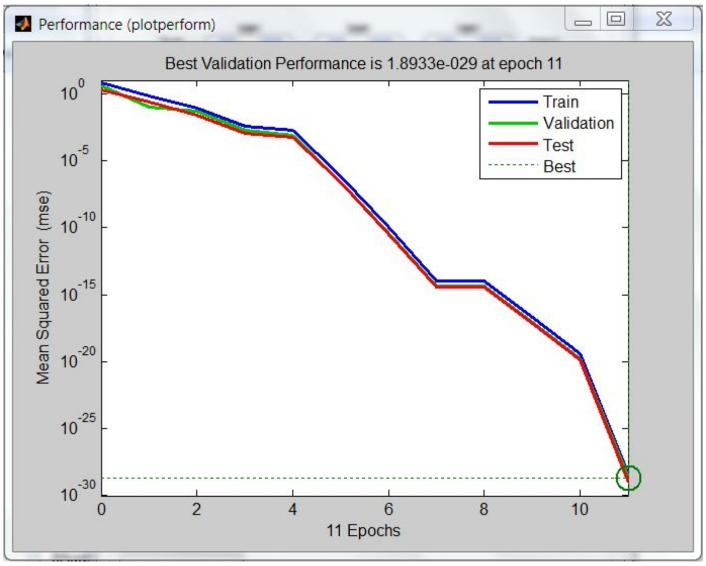

Figure 4: Performance for January.

On other hand, a fitting curve has been plotted to compare between the output of ANN and target, as shown in figure 5.

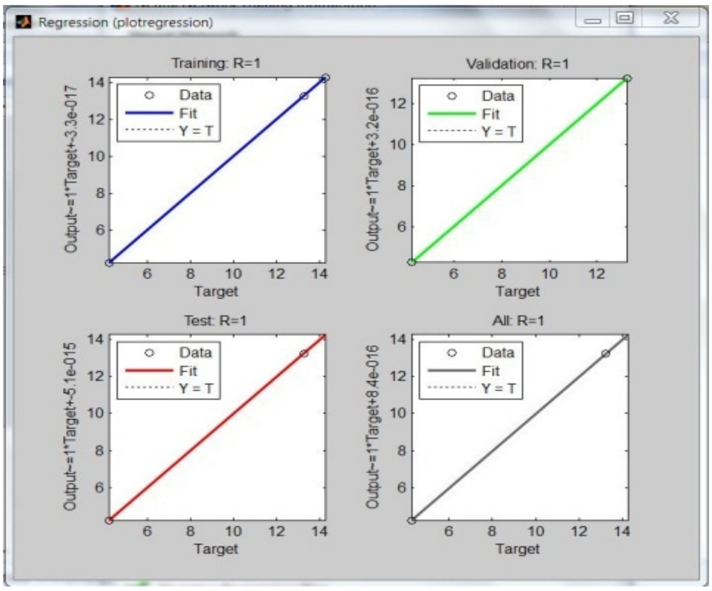

Figure 5: Regression for January.

For March, the performance and the fit regression have been explained, as shown in the following figures:

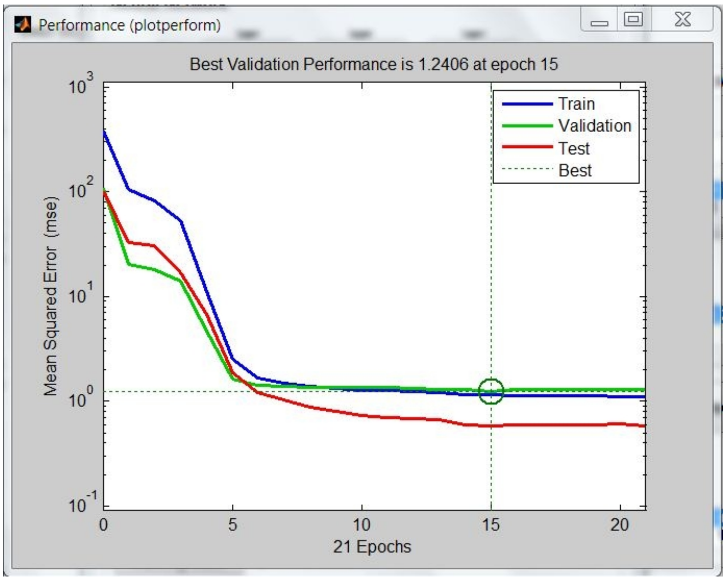

Figure 6: Performance for March.

After two months of training the performance has been reached to the best validation at epoch (15), see figure 6. Again a fitting curve has been plotted between output and target, see figure 7.

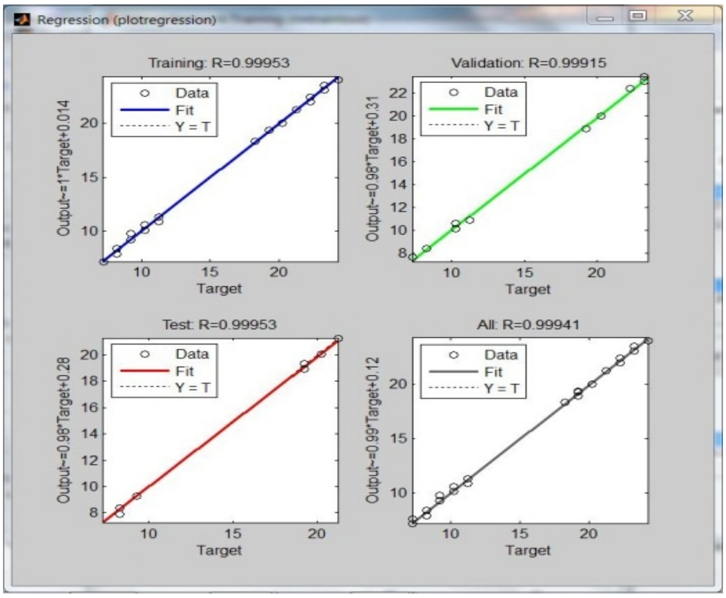

Figure 7: Regression for March.

For September, the change in weather has been effected in training of ANN, these increasing epochs to reach a validation, as shown in figure 8:

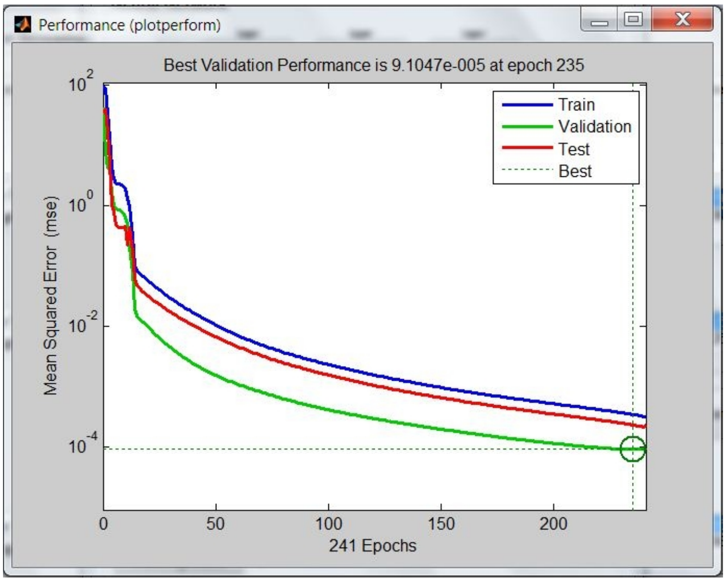

Figure 8: Performance for September.

A comparison between the output and target has been shown in figure 9.

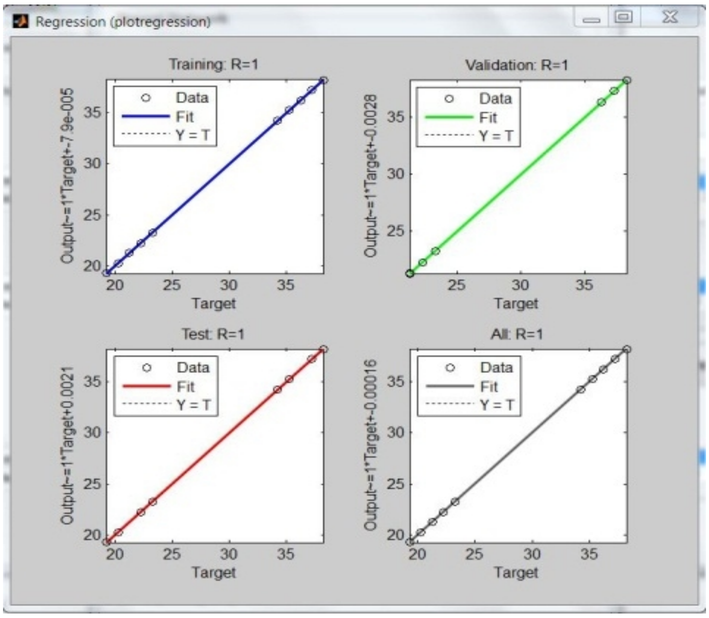

Figure 9: Regression for September.

The performance and the fitting curve between the actual outputs and the targets have been calculated for the twelve months. The result of the suggested ANN model has good performance, and low cast of implementation to give two weather temperatures one month ahead. For months that concurrence changing in weather because of solstice, the number of epochs has been increased but the output has been fitted with the target as shown in figure 9. The future work may be involved many input parameters to ANN model such as pressure, and output (besides to two weather temperatures) the rainfall predicting, that is effected by weather temperature and pressure.

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