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prediction of Solar Radiation Using Artificial Intelligence technique for Najaf City

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Abstract

In present paper, the artificial Intelligence (AI) have been investigated in order to estimation of monthly mean solar radiation in Najaf city. The suggested model were trained and tested using four years data (1995 - 1998) of monthly mean solar radiation, sun shine duration, Extraterritorial radiation and monthly mean ambient temperature for present month as an input and the output will be the estimate solar radiation , then tasted with monthly data of the trained years. The architecture of AI which represented by the artificial neural network (ANN) model was the model was the multi layer precipitation architecture and has three layers. An ANN was constructed, trained, and tested for a different numbers of neurons in its hidden layer. The best result was obtained with 4 neurons, where Determination Coefficient (R^2), Root Mean square Error (RMSE) ,Mean Percentage Error (MPE) were found to be 0.98 , 1.1 MJ/m^2 , 2 % for testing values. The results show that the Artificial Intelligence is powerful an alternate technique in Monthly mean solar radiation estimation.

تخمين الاشعاع الشمسي لمدينة النجف باستخدام تقنية الذكاء الاصطناعي

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الخلاصة

في هذه الدراسة قد تم توظيف تقنية الذكاء الأصطناعي (AI) لتخمين المعدل الشهري لقيم الأشعاع الشمسي لمدينة النجف. أن النماذج المصممة اختبرت باستخدام البيانات لمدة (1995- 1998) والتي تضمنت المعدلات الشهرية لقيم ساعات السطوع الشمس و قيم الإشعاع خارج الغلاف الجوي و درجات الحرارة كمدخلأت النموذج وستكون المخرجات قيم ألإشعاع الشمسي. أن التركيب المعماري للنماذج الشبكة العصبية من النوع المتعدد الطبقات. أن الشبكة العصبية ألاصطناعية أنشأت واختبرت باستخدام عدد من العصبيات في الطبقة الخفية للشبكة. أن أدق النتائج تم الحصول عليها باستخدام 4 عصبيات في الطبقة الخفية للشبكة حيث أن معامل التحديد(R^2) والجذر ألتربيعي لمعدل الخطأ (RMSE) و المعدل الخطأ النسبي(MPE) كانت 98% ، 1.1 ميكاجول\م^2 ، 2. للقيم المختبرة وقد أظهرت النَتائِجَ بأنّ تقنية الذكاء الاصطناعية هي تقنيةٌ بديلة وممتازة في تخمين قيم ألإشعاع الشمسي.

1-Introduction

Solar energy is the most ancient source of energy; it is the basic element for almost all fossil and renewable types. Solar energy is freely available and could be easily harnessed to reduce our reliance on hydrocarbon-based energy by both, passive and active designs. Precise solar radiation estimation tools are critical in the design of solar systems. Using solar energy necessitates an exact estimation of solar energy in proposed locations This is usually possible through solar measurement equipments while these devices are not available in some of remote or rural locations that specially have potential of solar installation. Even locations with these devices, the maintenance and logistics are enormous. Using prediction tools such as solar models are one of the best methods to have a good estimation of solar potential [1,2].

The artificial Intelligence (AI) which represented by Artificial neural network (ANNs) are mathematical models capable of determining a non-Linear relationship among different data sets [3]. ANNs are universal function approximates that can be applied to problems in which there is no knowledge about the relevance of the input variables. The forecasting of the atmospheric elements is an application of scientific technology to predict the state of the atmosphere for limited future time, Thus the atmospheric scientists are made by collecting quantitative data about the Multi-Layer Perception current state of atmosphere by using scientific understanding of atmospheric process to evaluate how the atmosphere will behave for the next future short term. The solar radiation values are important and required by solar engineers, architectures, agriculturists and hydrologists for various applications such of solar heating, cooling, air conditioning systems, building's interior designs [4-7]. For example, the knowledge of variation in solar radiation has a considerable value in predicting expected air temperatures [8-10]. Artificial Neural Network (ANN) technique can be employed as an alternative method, therefore predicting of rather complex atmospheric phenomena, thus it became a parallel computational model in addition to the traditional methods of weather perdiction'the important characteristic of ANN, this future makes ANN technique very active and accurate in application field for solving highly non

linear atmospheric phenomena [11].The aim of the present work is to employ AI . The so-called multilayer percptron (MLP), in order to estimate solar radiation using some meteorological parameters such as sunshine duration , extraterrestrial radiation and the maximum air temperature.

2- Artificial Intelligence

ANN is a branch of Artificial Intelligence which was developed in order to simulate the biological structure of the human brain [12] The Multi-Layer precptron (MLP) is the most used ANN for non-linear modeling , It is a feed for ward net work , typically trained with back propagation , thus it is the most popular nonlinear ANN architecture , employed wide variety of problems in applied atmospheric sciences . Even the simplest kind of a MLP network with a sufficient number of processing elements is called a universal approximate due to its ability to approximate any nonlinear relationship inputs and outputs to any degree of a accuracy [12,13] Conceptually , the MLP architecture consists of an input layer ,one or more hidden layers as shown in figure 1.

In fact it has already been used in ecology previously by [12, 15, and 16]. An MLP is formed by elementary units, the so called neurons. Neurons carry out a non-linear processing of their inputs, being their output computed. In present work MPL has been employed for short time prediction of ambient air temperature. The input parameters to the ANN are solar radiation, sunshine duration, extraterrestrial radiation and the air temperature for the day the ambient air temperature prediction day. A total of data 5475 for training and 1825 for test were used for Baghdad station (33.34 ^{o}N 44.45 ^{o}E), the architecture of ANN model was the multilayer perception has three layers, the first is the input with five inputs, the second is the hidden layer and the last one is the output layer. The network was trained and tested for different number of neurons varying from 2 to 10 neurons in hidden layer. In order to evaluate the . The accuracy of AI models was evaluated using;

The coefficient of determination (R^2) :

$$R^2 = 1 - \frac{(G - G^{\wedge})^2}{(G - G^{-})^2}$$

The root mean square error (RMSE) :

$$RMSE = \left\{ \frac{(G - G^{\wedge})^2}{n} \right\}^{1/2}$$

The maximum percentage error (MPE) :

$$MPE = max\, 100 \left| \frac{(G - G^{\wedge})}{G_i} \right|$$

Where G are the measured values, $G^{\wedge}$ are the calculated values, n is the number of data points and G^{-} is the mean of the measured values.

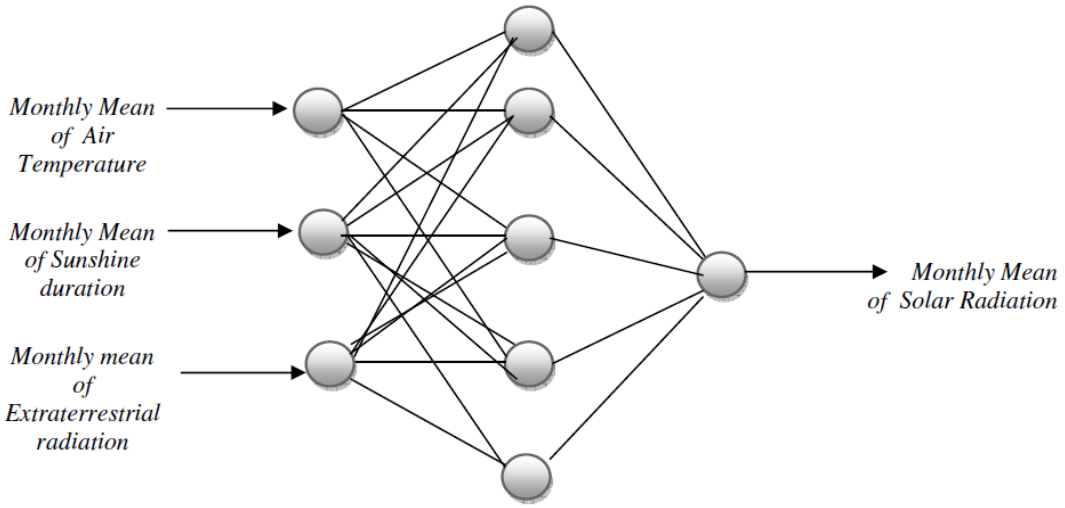

Fig 1: The main architecture of MLP artificial neural network

3-Study area and Climate

The study was carried out for Najaf city which is located about 160 km south of the capital Baghdad near the western branch of the Euphrates River, Najaf city with average elevation of 4000 m above sea level (ASL) area of about 2.5 million square kilometers, as shown in Figure 2.

Najaf has a Subtropical Arid climate, The average annual temperature is 25°C with daily mean temperature 13.3°C in winter and 35.2°C in summer ,According to data taken by Iraqi Meteorological Organization and Seismology (IMOS), the hottest months are July with maximum mean(46°C) and August (43 °C) while the coldest months are January with minimum mean (6°C) and December (4°C).Total annual precipitation is 102.9 mm in the city. A rapid increase in population and urbanization has resulted significant changes in land cover of the city especially over the last fifty years.

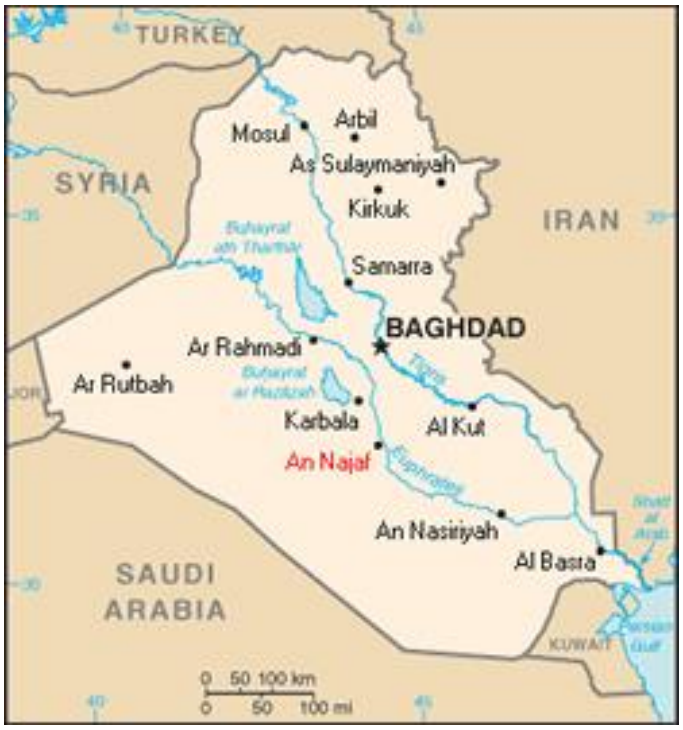

Fig 2: The map of Iraq.

3-Result and Discussion

ANN models with different number of neurons in hidden layer was developed to estimate Global solar radiation using the training a MLP neural network. The AI model were trained for the years (1995 - 1997) as shown in figure 3 and tested for the year 1998 as shown in figure 3. The tests began with a network contain 3 neurons in its hidden layer until reaches 8 neurons, From these tests the resulted output of the network was found to be very close values are shown in figure 4.The calculated determination coefficient (R^2), Root Mean Square Error (RMSE), Mean Absolute Percentage Error (MAPE) values of the error of the AI estimated global solar radiation was tabulated in table 1, for each AI model. From table (1) the best result was obtained for 4 neurons AI model where R^2, RMSE, MAPE values were found to be 0.98 , 1.2 M jm^{-2}, 2.6 % .

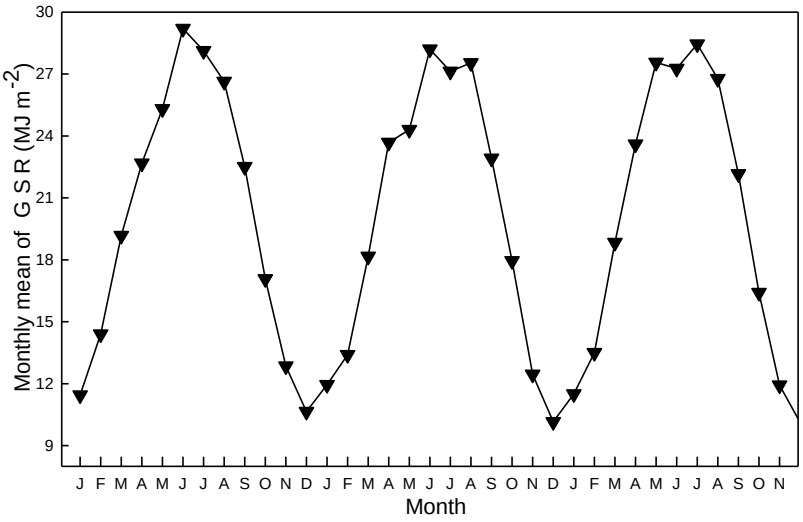

Fig 3: Solar radiation data which used in present study for training AI for Najaf city (1995-1997)

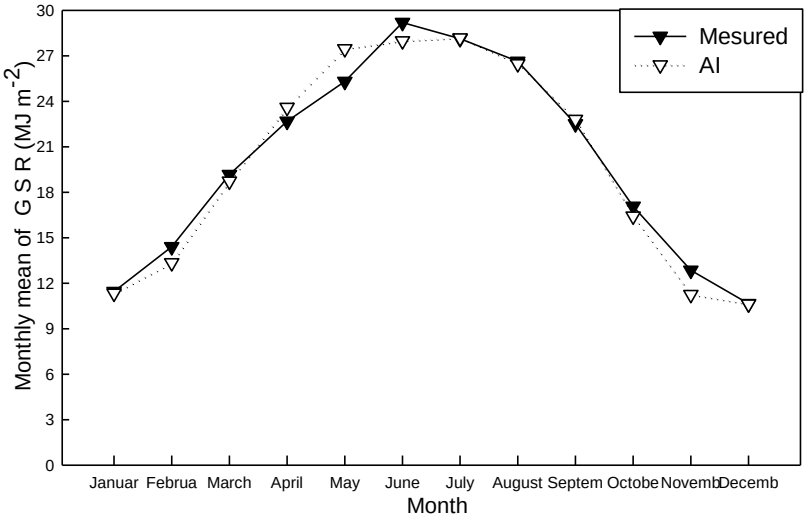

Fig 4: Comparison between measured and estimated global solar radiation using AI in Najaf city for the year 1998.

Table 1: Statistical indicators of the empirical models proposed by [4,5 and 6] and AI models estimation errors for monthly Mean daily global solar radiation.

AI Model No	R^2	MPE(%)	RMSE(MJ/m^2)
Model 1 (3 neuron)	97	2.2	1.4
Model 2 (4 neuron)	98	2	1.1
Model 3 (5 neuron)	96	6	1.25
Model 4 (6 neuron)	91.9	2.9	3.5
Model 5 (7 neuron)	93.8	3.4	2.8
Model 6 (8 neuron)	92.6	2.99	3.2

4- Conclusion

The results of the validation and comparative study indicate that the AI based estimation technique for global solar radiation is more accurate for predicating then the classical regression models proposed by other researchers for Iraq and other developing countries which have a shortage in solar radiation equipments because it is relatively expensive .This work confirms the perfect ability of AI of Global solar radiation also the results refer that the AI model seems promising tool for predicting other meteorological elements where there are no stations to monitor these elements.

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