

# A Survey on Solar Energy Prediction using AI based Techniques

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## Abstract

*Artificial Intelligence termed as the coined term AI is being used in several applications; wherein the data complexity is high of the size is non-trivially high. This paper presents a survey on AI allied techniques for solar irradiation prediction problems where the challenges mentioned for the basic AI problems to encounter have to pertain keeping in mind the size and the complexity of the data. The various ANN based structures with the relevant challenges have been cited. The mathematical computation of the error descent for neural architectures has also been provided. It is expected that this survey would pave a path for future researchers in designing their research around the framework of ANN design.*

**Keywords:** *Solar energy, artificial neural network (ANN), ANFS- adaptive neuro-fuzzy system*

## INTRODUCTION

There are some major challenges in solar irradiation prediction using ANN. These challenges include:

1. Random variations in movie success
2. Deciding important parameters (features) which yield effect on classification accuracy
3. Computing features
4. Designing an appropriate neural network model which would work accurately in varying paradigms of structural classification
5. Training such a network
6. Testing the network and to ascertain that it yields high accuracy

Thus, designing a completely automatic and efficient system for movie success prediction is a major challenge. Generally, such a determination system is capable to perform three main sequentially subtasks namely extraction of feature, selection of feature and classification. They are defined as under:

**1. Computation of Critical Parameters or Features:** This step is responsible for extracting all possible features for movies

that are expected to affect movie success the most.

**2. Optimizing Feature Values:** This step is responsible for reducing the dimensionality by removing irrelevant or futile features and searching for the best significant features to get rid of the cause of dimensionality and reducing computation complexity.

**3. Training and Classification:** First and foremost, the machine or artificial intelligence system requires training for the given categories. Subsequently, the neural network model needs to act as an effective classifier. The major challenges here is the fact that movie success vary significantly in their parameter values due to the fact that the parameters for each solar irradiation is complex and hence it becomes extremely difficult for the designed neural network to find a relation among such highly fluctuating parameters.

Generally, ANNs have a knack of finding the relevant connections among the non-trivial data sets that have similarities

hidden. The main challenge or shortcoming is to design the ANN structure using a training algorithm that is:

**1. Stable:** The inference is the fact that using such an algorithm, the errors should monotonically decrease.

**2. Fast:** The algorithm should not have excess time complexity.

The challenge faced in the training rules in the ANN design have to be observant to the changing weight that rules the erroneous data predictions off the paradigm.

**ARTIFICIAL NEURAL NETWORK (ANN)**

Artificial Neural Networks (ANN) is the practical epitome of AI based systems which can be designed and implemented on computational machines as shown in

Figure 1. The attributes of the fundamental ANN structure are the following:

1. Parallel path structure having data coming in simultaneously.
2. Adaptive way to learn from equivalents of experiences also called weights.

If we consider signals:

$x_1, x_2, \dots$ . Coming via different paths, then the mathematical model of the ANN can be given by:

$$y = \sum_{i=1}^n x_i w_i + \theta$$

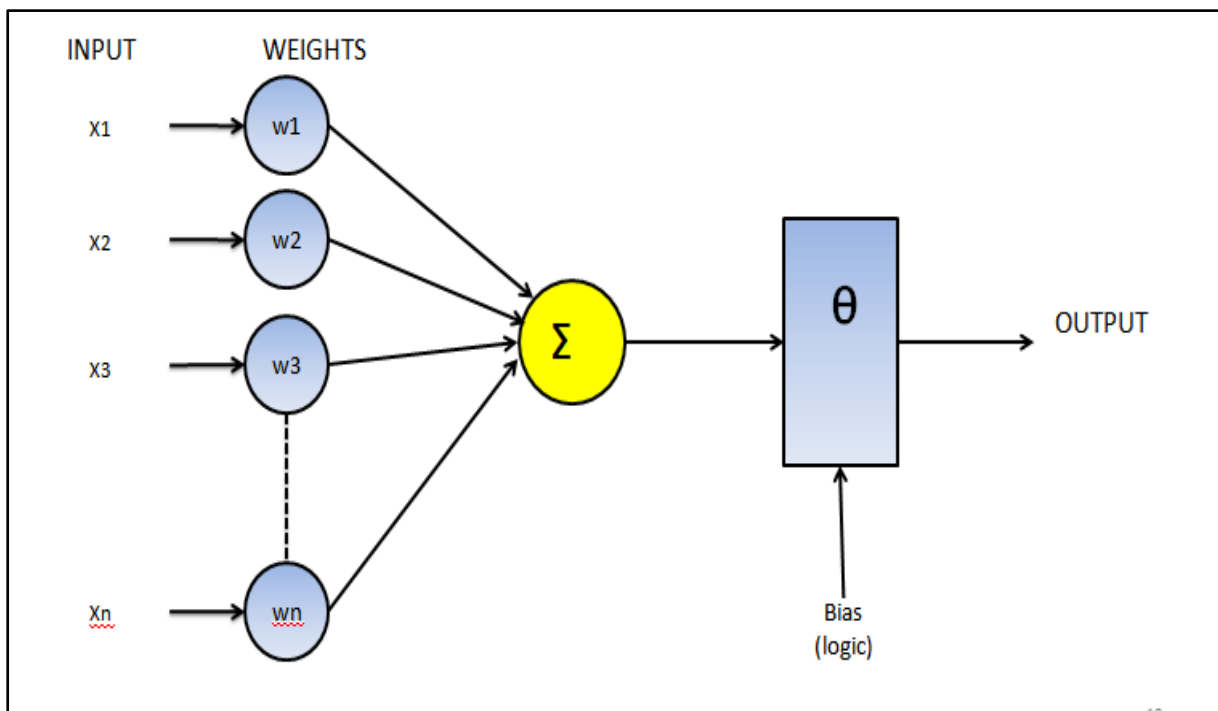
Here,

X represents the parallel input stream

Y represents the final decisive output

W represents the experiences hiterto said weights

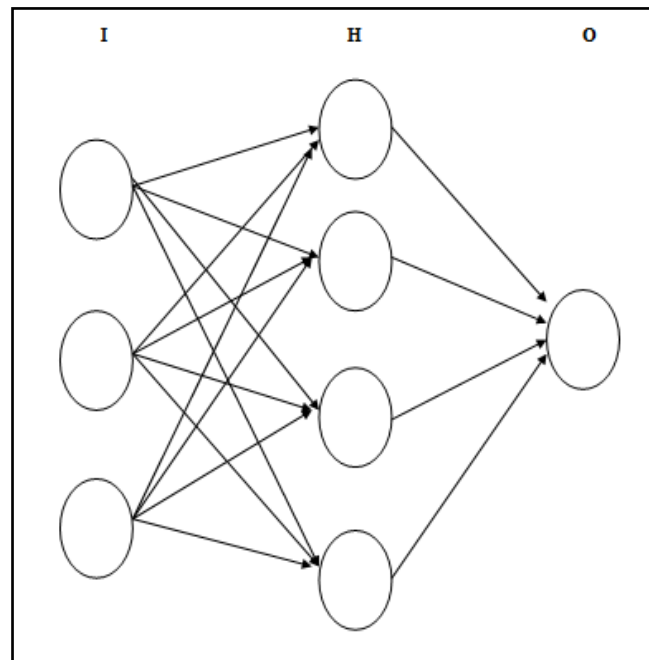
$\Theta$  represents the bias



**Figure 1: Mathematical Counterpart of ANN.**

The internal structure of the ANN design can be understood by the interconnection of the input layer, the subsequent hidden

and the output layers connection with each other for the time series and classification problems as shown in Figure 2.



**Figure 2:** Internal Processing of ANN.

**PREVIOUS WORK**

In the year 2016, [1] SaadSoud et al. recommended a system that was primarily aimed towards the batch mode of active learning that is a sub-class of machine learning. In this technique the authors made an attempt to combine the positive attributes of active reinforced learning with wavelet neural learning for the purpose of solar irradiation prediction. The data-pre-processing stage was aimed at attaining data that was as diverse as possible with an aim to get a well rounded or holistic approach for the parameter or feature values. The authors also explored the mutual similarity among the features selected for training the neural network designed. The approach was termed as joint exploration-exploitation algorithm. The authors also suggested the use of a balancing parameter  $\beta$  that was used to justify or normalize the similarity index between the training parameters. From the results, it was revealed that the recommended algorithm outperformed the baselines approach.

In the year 2016, [2] Sharma et al. recommended a technique that was based on the construction of a system that found

the parameters in a family of arcs. The data collected was form the cloud database and was indeed useful in creation of a data based semantic arc system with sentiment scale analysis. The authors investigated the power of the recurrent learning based on iterative learning for problems. The authors recommended that more solar data could have a better well rounded prediction paradigm. The raw data was collected from sources and cleaned prior to feeding the AI based paradigm.

In the year 2013, [3] SaadSaoud L, Rahmoune F et al. recommended a technique based on deep neural networks and deep learning in conjugation with tag extraction approach. The technique could be comprehended as a higher level semantic approach with the inclusion of tags as the extra parameters. The tags that justifiably affect the performance of the solar data were chosen. It was shown that the recommended system could evaluate tags better than existing tag extraction systems and hence would yield better accuracy.

In the year 2011, Zhao et al.[4] recommended a system using the Bayesian

Back propagation that was used for the prediction of movie success prediction based on the BPNN. The system was enhanced using the multi-class or multi dimensional probabilistic approach with splitting the hyper-plane of the SVM classifier. It was shown that the recommended system outperformed existing systems.

In the year 2011, Zainuddin Z, Pauline et al. [6] used the wavelet neural sure for solar data prediction. The approach used WNN can prove to be effective in time series prediction problems. The major lacking aspect seen in this approach was the lack of data pre-processing so as to make the system learn additional parameters in prediction with higher accuracy. While hybrid systems have been recommended, it was not shown whether the algorithm designed follows the steepest descent approach for error reduction. The final results did have a graphical representation making it more palatable. The approach used a very similar polarity count mechanism trying to extract polarized meanings form review sentences. Thus the technique exploited the fundamental property of the wavelet transform for data smoothening prior to training.

In the year 2013, Babu GS, Suresh S et al. in [7], presented an approach that used meta-cognitive approach with RBF i.e. radial basis function for time series prediction and classification problems. It was shown that the recommended system worked vector averaging model. The authors designed a methodology used in this study considering the short-term historical time series classification as well as the day of week as inputs. The authors were intelligent enough to execute data structuring in a way so as to train the prediction system in the most effective manner.

In the year 2015, Sivachitra M, Vijayachitra S et al. in [8] used the fully

functional complex link of ANN structures for time series and the ubiquitous classification problems. They used previous data samples to inadvertently tell the neural network about the day of the sample. It is commonly used as the neural network needs to be fed using previous samples. The previous point is effective since the neural network may try to find out the correlation between the present day's data set. That is to say, adding an additional feature in the learning process makes it adaptive to learn.

In the year 2012, Hu et al. in [9] recommended in the paper on complex valued neural networks problem of prediction problems using the gray line artificial neural networks (GMANN). The approach was shown to perform better than the conventional ANN structure. The authors recommended designing an optimized system with optimized values of neurons, hidden layers, training functions and training algorithms. It should be noted that there is no rule to find the number of layers in the hidden layer of the number of neurons. Thus an exhaustive search needs to be carried out. The authors did the same and lay down the results found by them.

In the year 2013, A Khare et al. In [10] recommended the particle swarm approach for solar PV data prediction problems. Recommended a technique to predict near future PV relevant data. They rather focused on weighted sums of movies which had a significant impact on the data sets. They made a comparative analysis of the basic optimization approaches. The authors developed a technique in which the expert view would be taken from the PSO to train the neural network along with historical data. Subsequently, the ANN would forecast or predict values. The recommended system results challenge the weak form of the solar irradiation PV data by demonstrating much improved and better predictions, compared to other approaches.

**ERROR DESCENT COMPUTATION FOR ANN DESIGN**

Let  $\Delta\omega$  be the amount by which the weight is updated in every iteration.

Then  $\Delta\omega$  is mathematically computed as:

$$\Delta\omega = J^T J + \mu I^{-1} J^T e$$

Where,

$\omega$  the weight vector,

$I$  is the identity matrix,

$\mu$  is the combination coefficient,

$(Q \times R) \times N$  the Jacobian matrix

$J$  and  $(Q \times R) \times 1$  the error vector  $e$  are defined as

$$J = \begin{bmatrix} \frac{\partial e_{11}}{\partial \omega_1} & \frac{\partial e_{11}}{\partial \omega_2} & \dots & \frac{\partial e_{11}}{\partial \omega_N} \\ \frac{\partial e_{12}}{\partial \omega_1} & \frac{\partial e_{12}}{\partial \omega_2} & \dots & \frac{\partial e_{12}}{\partial \omega_N} \\ \dots & \dots & \dots & \dots \\ \frac{\partial e_{1M}}{\partial \omega_1} & \frac{\partial e_{1M}}{\partial \omega_2} & \dots & \frac{\partial e_{1M}}{\partial \omega_N} \\ \dots & \dots & \dots & \dots \\ \frac{\partial e_{Q1}}{\partial \omega_1} & \frac{\partial e_{Q1}}{\partial \omega_2} & \dots & \frac{\partial e_{Q1}}{\partial \omega_N} \\ \dots & \dots & \dots & \dots \\ \frac{\partial e_{QR}}{\partial \omega_1} & \frac{\partial e_{QR}}{\partial \omega_2} & \dots & \frac{\partial e_{QR}}{\partial \omega_N} \end{bmatrix}$$

Where,

$Q$  is the number of training patterns,

$R$  is the number of outputs,

$N$  is the number of weights.

Elements in error vector  $e$  are calculated by

$$e = \begin{bmatrix} e_{11} \\ e_{12} \\ \dots \\ e_{1R} \\ \dots \\ e_{Q1} \\ e_{Q2} \\ \dots \\ e_{QR} \end{bmatrix}$$

$$e_{qr} = d_{qr} - 0_{qr}$$

Where,

$d_{qr}$  and

$0_{qr}$  are the desired output and actual output respectively

And training pattern is  $q$ .

The error function  $E$  can be computed as:

$$E(\omega) = \frac{1}{2} \sum_{q=1}^Q \sum_{r=1}^R e_{qr}^2$$

Where ,

$e_{qr}$  is the error at output  $r$ , obtained by training pattern  $q$

The  $N \times N$  hessian matrix  $H$  is given by:

$$H = \begin{bmatrix} \frac{\partial^2 F}{\partial \omega_1^2} & \frac{\partial^2 F}{\partial \omega_1 \partial \omega_2} & \dots & \frac{\partial^2 F}{\partial \omega_1 \partial \omega_N} \\ \frac{\partial^2 F}{\partial \omega_1 \partial \omega_2} & \frac{\partial^2 F}{\partial \omega_2^2} & \dots & \frac{\partial^2 F}{\partial \omega_2 \partial \omega_N} \\ \dots & \dots & \dots & \dots \\ \frac{\partial^2 F}{\partial \omega_1 \partial \omega_N} & \frac{\partial^2 F}{\partial \omega_2 \partial \omega_N} & \dots & \frac{\partial^2 F}{\partial \omega_N^2} \end{bmatrix}$$

Where,

$N$  is the number of weights.

**CONCLUSION**

The previous discussions about the basics of Artificial Intelligence and Artificial Neural Networks indicate the fact that neural networks can derive meaning from highly complex data. The different approaches in the relevant field have been cited and exemplified in brief. The various computation parameters in the computation of the error of the ANN time series applications have been also been presented in the approach.

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