Artificial Neural Network Based Weather Pridiction System

Mallikarjun Mudda , Farheen, L.Saraswathi, Leharika Prakash

Abstract: In this paper, the prediction of weather using the artificial neural networks (ANN) with the back propagation algorithm and LM algorithm is done. A better training algorithm will help in providing accuracy in less time, a factor which every person demands nowadays. There are many widely used algorithms for the design of ANN but the most secure and reliable one is the back propagation algorithm. This algorithm focuses on using and utilizing the feedback of errors from the networking domain. It then calculates and evaluates the errors and gives it to the system again, to ensure that the errors are lessened in a faster pace. Hence the method of back propagation allows the reduction of errors in both a faster and a precise manner. An advantage of this approach is that a parabola is obtained as a result, which makes it easier for determining the predicted outputs. It also requires the least number of iterations to perform the analysis, which helps in getting quicker results. The major reason why this algorithm is to be used is that it is Fast, Stable.

Keyword: Back propagation, Levenber-Marquardt, perceptron, root mean square error.

I.INTRODUCTION

The application of science and technology is forecasting of weather which is used to detect the condition of the atmosphere of a given location. By using scientific atmospheric processes to showcase how the atmosphere will evolve and by gathering quantitative data about the present state of atmosphere the weather forecasts are made. In order to solve the equations that describe the atmosphere, the disordered nature of the atmosphere and the huge computational power are required. As the difference in forecasting time and the present time is being made increasing, the error in the measurement of initial conditions and the inaccurate understanding of atmospheric process mean that the forecasting of weather has become less accurate. The weather forecasts have different end uses. In protecting the life and property, the weather warnings play a major role in forecasting. In the field of agriculture, forecasts that are based on temperature and precipitation are vital and also to the traders within the markets of commodity. In order to calculate the demands in future coming days the temperature forecasts are used by the companies of utility. Artificial neural networks (ANN) can deal with dynamic and non-linear process of weather. The paper inspects the application of ANN approach by developing successful and reliable nonlinear predictive models for examination of weather. Data intensive model is established using data mining technique. It also compares and evaluates the performance of the already developed models by making use of different transfer functions, hidden layers and neurons to predict the highest temperature for total 365 days of the year. When compared to traditional and numerical methods the research states that ANN is the best approach for the weather prediction. Depending upon every day basis, people decide what to wear on that particular day by making use of weather forecasting. Since the outdoor activities majorly depend upon the climatic conditions such as followed by heavy rain, snow and the wind chill. So, the prediction of weather can be used to plan the activities around these events, and to plan ahead and sustain them. Thus we have proposed a model of weather forecasting using Artificial Neural Networks (ANN) in order to predict weather in a very effective and efficient way and to help people overcome all such difficulties. The ANN reduces the error using different algorithms and gives us a predicted value which is almost equal to the actual value and this is the main advantage which ANN has over other weather forecasting methods. So, to determine the weather trend in future this network is simulated over newer data. The extraction of data, detecting of trends and also prediction pattern called generalization which is not provided during training are the other advantages of artificial neural network. An artificial neural network is a tool which is strong and data-driven. It is also self-adaptive, flexible computational tool which has the capacity to capture and handle nonlinear and tough underlying characteristics of any physical process with high grade of accuracy. Figure 1 represents the basic architecture of artificial neural networks (ANN) which consists of three layers. The first layer consists of input neurons, the second layer contains hidden neurons, and the third layer consists of the output neurons. In order to give desired outputs in response to the training set of inputs the supervised neural networks are needed to be trained which can be done by providing the network with desired input and output matching patterns.

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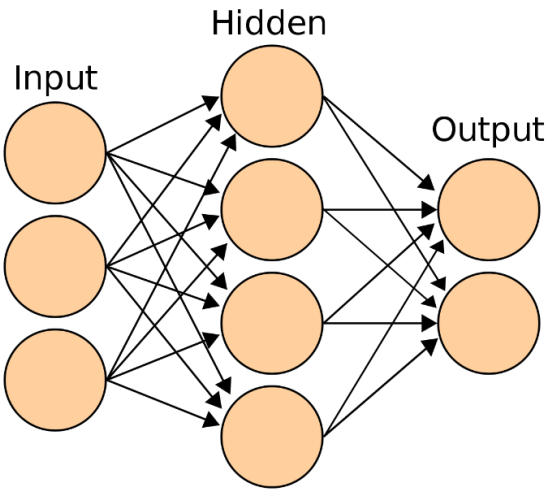

***Fig. 1**: Basic ANN architecture*

II. LITERARURE SURVEY

Many efforts were made to predict the weather but none of the methods are satisfactory due to the non linear nature of the weather. In this section a survey done on different papers of similar projects is writtenIn [1], described what actually are the neural networks? And how the neural networks have evolved and its importance in our day to day life to save more time and work. The paper gives the advantages and limitations of the neural networks. It also concluded the future work that can be done to solve the limitations of neural networks. In [2], mentioned a rapid method to predict the weather conditions. The weather forecasting parameters include temperature, rainfall and humidity. They have used the feed forward topology for a back propagation neural network. It also gave the comparison between the gradient descent algorithm and LM-algorithm. It is concluded that Levenber-Marquardt algorithm performs at a rapid rate than many other training algorithms in neural networks. To predict the weather they have collected the data from past and present values of the weather. In [3], have given the model of LSTM(long-short term memory) technique to analyze the weather parameters like the temperature, pressure, precipitation, dew point, humidity etc. They have gathered the present and past values of the weather and using the values to train the neural network. The paper concluded that the LSTM is the fastest method among various neural networks. The artificial neural networks are not only used in weather forecasting but also in the medical diagnosis. In [4], have investigated between the feed forward technique and hybrid network. The paper concluded that the hybrid model can implemented successfully. In [5], the author discussed about the contemporary firework algorithm. This paper gives the method which is used to foretell the mean temperature. The paper concluded that the model proposed have produced the acceptable values. It is also written that the future work will be involved with the comparison of other prediction models with the existing models. In [6], the authors have done the experiments on various techniques of neural networks. Here the network was trained using the techniques of neural network such as BP algorithm, regression neural network, Fuzzy ARTMAP, optical neural network, radial basis function. They have noticed that the best results were obtained from the Fuzzy ARTMAP neural network. The Fuzzy ARTMAP can solve the limitations of ANN.

III. PROPOSED METHODOLOGY

A. The Back Propagation Algorithm:

The learning algorithms play a significant role in the design and building of an artificial neural network. Some models fail to predict or acquire the desired results due to the failure not using such algorithms. A better training algorithm will help in providing accuracy in less time, a factor which every person demands nowadays. Training process in artificial neural networks helps providing a link between the data present with us and the structure to be built. This can be any structure, depending on the choices and requirements of the user or the company. There are many widely used algorithms for the design of ANN but the most secure and reliable one is the back propagation algorithm. This algorithm focuses on using and utilizing the feedback of errors from the networking domain. It then calculates and evaluates the errors and gives it to the system again, to ensure that the errors are lessened in a faster pace. Hence the method of back propagation allows the reduction of errors in both a faster and a precise manner. However, there is a certain threshold limit set. Until the system doesn't reach the threshold limit, this algorithm can send back the values to the system. This limit is known as the maximum tolerable error. The system should satisfy these criteria in order to avoid failure of the system. If in case, there occurs a scenario where the tolerable error is not set in the system before hand, and the prediction analysis is done, then after a few iterations, a message is displayed stating that the system has failed. Hence, to avoid this condition, we use this parameter. Before describing the structure of the back propagation algorithm, let us brush through the basics of the artificial neural network. Some of them are listed below

: **i. Perceptron**

Introduced by Rosenblatt, a perceptron is a simple neuron that contains some threshold and adjustable weights. The factors wij denotes the weight from the j-th input to the i-th output unit. The other parameter wi denotes the weight of the vector of the i-th node, which is on the output side. Here, we obtain the set of both input and output value pairs present in the neuron, which is then combined in the further processes to obtain a system. In the equations below, x1 indicates all the sets of inputs y1 denotes the set of outputs obtained at the output side. K is a factor of perceptron, which can range to any value depending on the user requirement.

$$x1 = (x11,.....x1n)$$
$$y1 = (y11,.....y1m).....K \quad (1)$$
$$xk = (xk1,.....xKn)\,yK = (yK1,.....yKm)$$

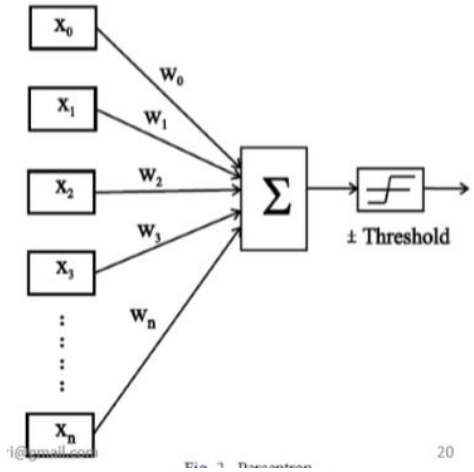

Fig. 2: *Block diagram of Perceptron*

These values are then combined and sent to the threshold system to attain the resultant error free system.

ii. Layers:

A layer is an accumulation of all neurons that is used to perform certain functions each neuron is named with either a particular number or letter, and it is normally assumed that the neurons are not connected to each other at all, either within the same layer, or different layers. All the neurons are interlinked with the input, output and the external environmental layers. Both the input and output layers have at least one neuron. There are a few neurons present in the hidden layer. This layer contains neurons present in both input and output layers, which are not visible externally as such, but perform functions within the layer. They act as a connection between the previous and the next layer in the neural network, hence are also known as featue detectors, due to their ability to respond to particular feature detectors in the previous layer.

iii. Weights:

Weights in neural networks stands for measure of strength present between the links of the layers. It determines the influence or the dominating neuron in the system. This is done by measuring the magnitude of each neuron. For instance, if the magnitude of neuron 1 is greater than that of neuron 2, then the neuron 1 has more influence on neuron 2.However, in the input side, weight gives less importance to the input values. Weights near zero mean that there is no change in the output. Negative weights mean that if the weight in the input side is made larger, then the weight in the output side reduces to some extent.

IV. Activation:

The activation function acts as the pathway between the input of the previous neuron and the output of the next neuron. Generally, this function can be any simple step function, or any complex function like the sigmoid function, depending on the input, output and the threshold variables.

V. Threshold Function:

A threshold transfer function is used to estimate the output obtained at the output layer of the network. Compared to other estimations, this function allows connections between all possible neurons present in the layers. This type of function or system is basically termed as a dynamic system due to the presence of various loops obtained at the neurons. The three common tyoes of threshold functions used are as follows:

$$\begin{aligned} g(x) &= 0 \quad \text{for } x < p \\ &= 1 \quad \text{for } x \geq p \\ g(x) &= 0 \quad \text{for } x < p \\ &= A_i \quad \text{for } x \geq p \\ g(x) &= 0 \quad \text{for } x < p \\ &= x \quad \text{for } x \geq p \end{aligned} \tag{2}$$

B. Functioning of the Back Propagation Algorithm:

The general flow chart of the back propagation algorithm is shown below. The steps are listed below. Firstly, the weights are given as input to the network. A load-forecasting model is then made using a multilayer neural network using this algorithm. The training is done in a supervised manner. The desired input is given and the weights are adopted to measure the error functions, which inturn provides a measure or estimation of the differences present in the input and the output values. The data of previous two years is used as input for training the network . The mean square error, or the root mean square error is calculated using the comparison of the predicted value and the actual value, which is hence sent back to the feed forward links. The back-propagation algorithm modifies and changes the weights of all links present in the internal parts of the network, to minimize the error. If the error gradient still exceeds the threshold value, a new epoch is brought into picture. Finally, after processing all the epochs, its performance is judged by calculating MSE. After all these steps, the result is then sent for prediction and generalization, which hence produces the resulted graphs based on the RMSE and the gradients. The formula for MSE is given below. The RMSE is used to predict as well as calculate the accurate point in the graph where the predicted value exists. This point is known as the zero error point, where the exact value exists, without any error. This formula for MSE was first introduced a long time ago, however, there are modifications to it, according to the algorithm we use. Here, the mentioned formula is the most basic of all the formulas.

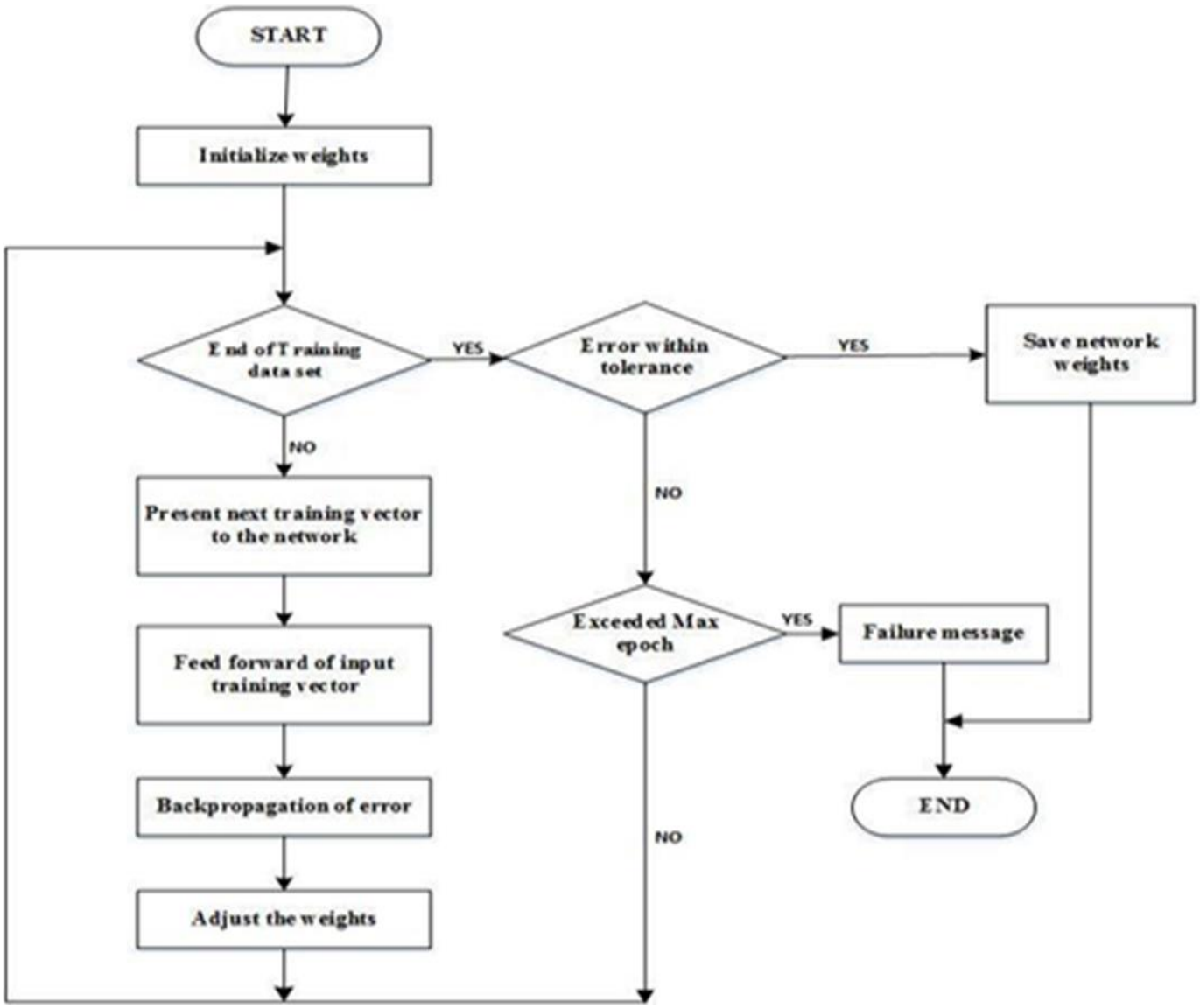

Fig. 3: *Flowchart of Back propagation algorithm*

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(y_i - \tilde{y}_i)^2 \qquad \text{-------- (3)}$$

C. LM Algorithm:

This project uses artificial neural networks along with an algorithm known as Levenberg – Marquardt algorithm, which is one of the algorithms under the back propagation algorithm. A weather forecasting model is developed using this algorithm.The LM algorithm is an algorithm usually used to minimize the MSE to the maximum extent. It is a part of the learning methods known as ‘‘pseudosecond order methods.” The other two algorithms such as the Standard gradient descent algorithms use only error versus weights graph to obtain the lowest error by controlling the directions of the weights in the system. This algorithm uses the Hessian format. If the use of quadratic systems in the networks is initialized, compared to the linear systems, these systems can predict the errors in one step. An advantage of this approach is that a parabola is obtained as a result, which makes it easier for determining the predicted outputs. It also requires the least number of iterations to perform the analysis, which helps in getting quicker results. The flowchart of the LM algorithm is displayed underneath. The major reasons why this algorithm is to be used is that it is: a) Fast b) Stable.

D. System Design:

- First, the data is obtained. This is done by taking the values of days and daily maximum temperature readings of years ranging from 1965 to 2015. This prediction is done for the year 2016 using all these parameters.
- This data is then checked and cleaned efficiently so that there is no error in the outputs obtained or the inputs. This is done by cross checking and analyzing each and every value in the input data to ensure perfect analysis.

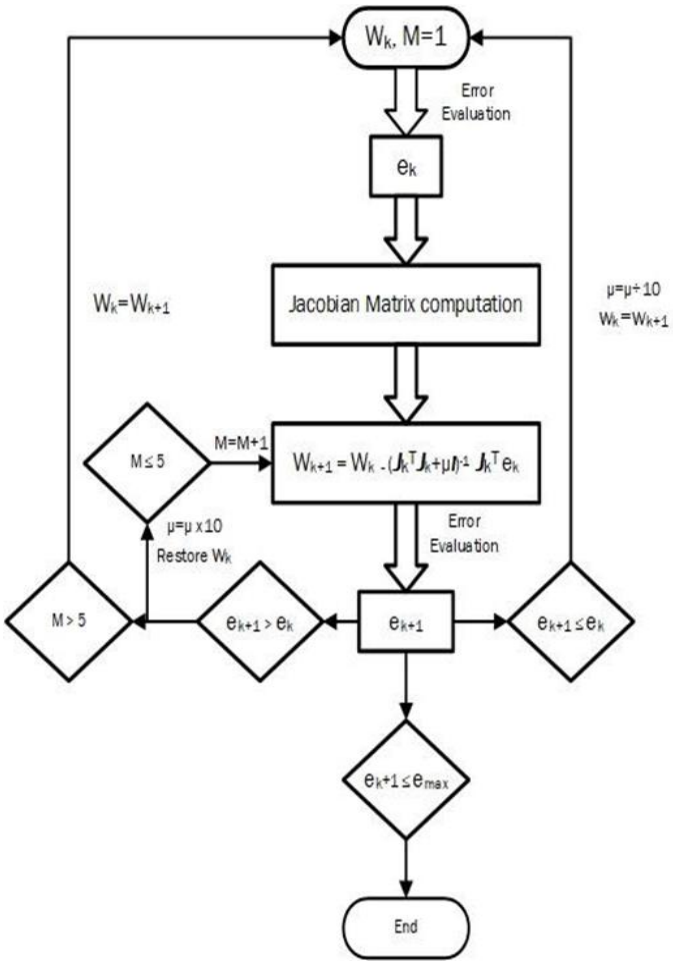

Fig. 4: *Flow chart of LM algorithm*

- The third and the crucial step is to design the artificial neural network using the input data, outputs, epochs, activation networks, weights, and layers. Before training the network, the data set is trained using the training algorithms, and also the threshold values in consideration.
- The input values are interconnected with the output values using neurons which are also known as perceptrons, and each perceptron is interlinked in the layers. The hidden layer neurons are created in this part of the process, which hold the parameters which are to be predicted, also known as the outputs that the user really wants.
- After this section is produced, it is sent for testing to check whether the parameters are in par with the set threshold values and also if there is any errors in the input data.
- The hidden layers process the nonlinear data. The number of hidden layers should be selected using the trial and error method. The complexity of the network increases due to the presence of many hidden layers.
- This model generates output in terms of the RMSE and the number of neurons. Seventy percent of the dataset will be used for training and thirty percent of the dataset will be used for testing and validation.
- After being sent to testing, the temperature for the year 2016 is predicted from the resultant outputs.

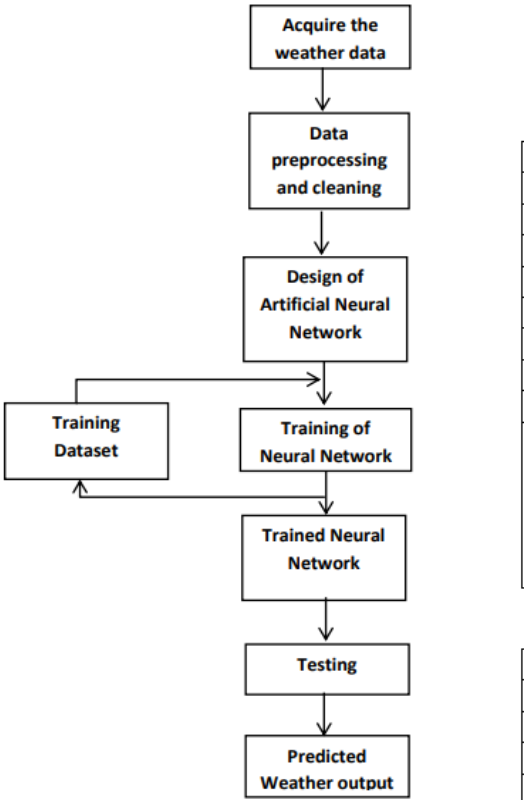

Fig. 5: *Weather prediction model design using artificial neural networks*

IV. RESULTS AND DISCUSSION

The results have been evaluated based on the following parameters:

1. RMSE wrt no. of hidden neurons
2. Gradient and validation analysis
3. Error histogram of validation and testing
4. Regression plot

TABLE I

Table of results and analysis

S. no.	Parameter	Value
1.	Zero error point	0.81835
2.	Training RMSE	0.80276
3.	Validation RMSE	0.79873
4.	Test RMSE	0.79607
5.	Combined RMSE(final)	0.80112
6.	Gradient(at epoch 15)	0.86007
7.	Mu(at epoch 15)	0.001
8.	Validation checks (at epoch 15)	6

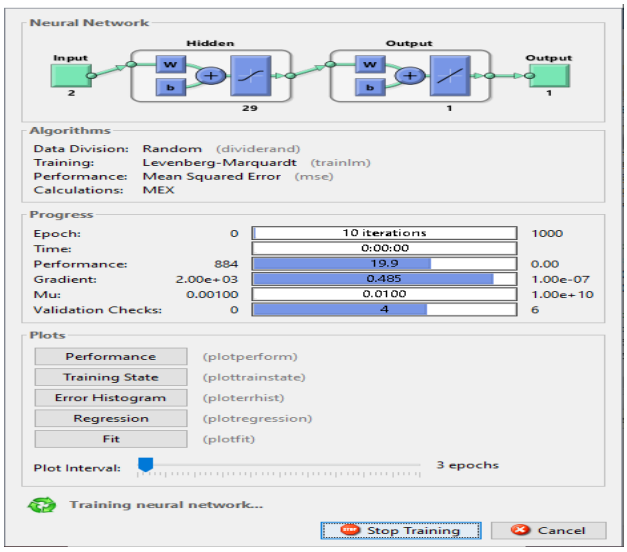

Fig. 6: *ANN Network*

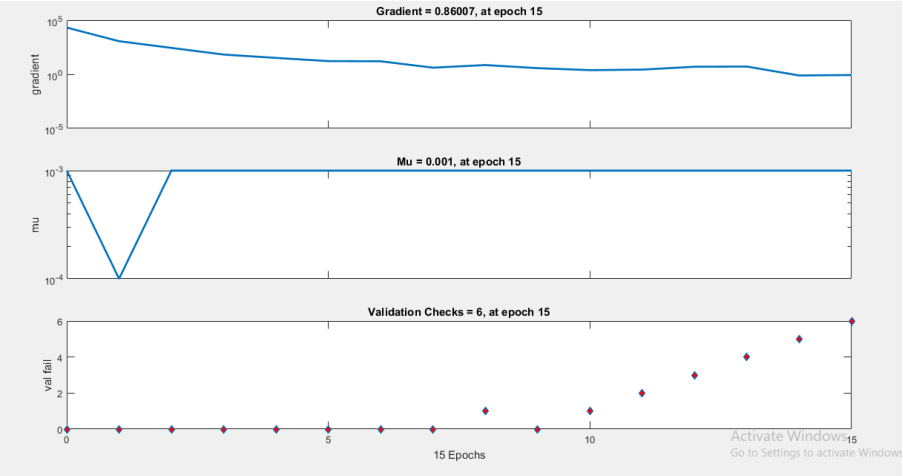

Fig. 7: *Gradient, Mu, and validation checks at epoch 15*

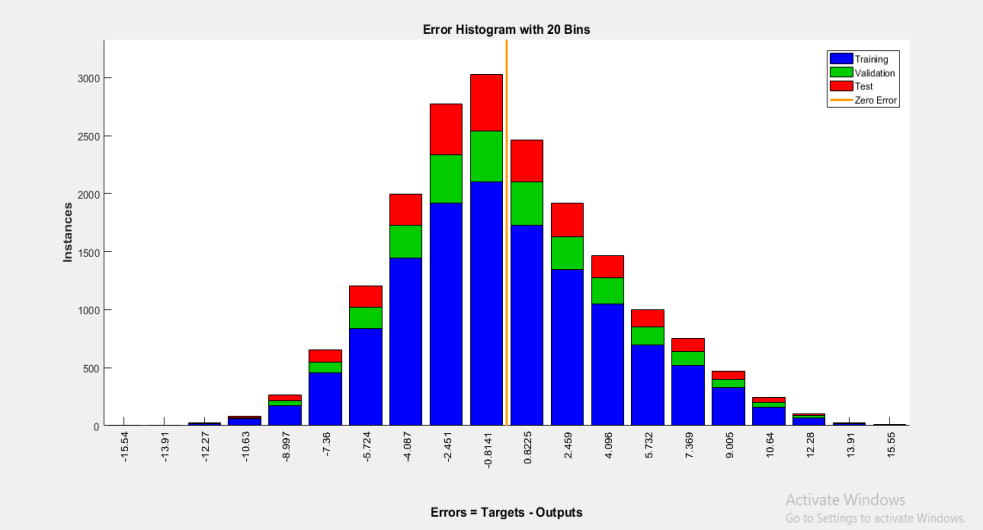

Fig. 8: *Error histogram for the analysis*

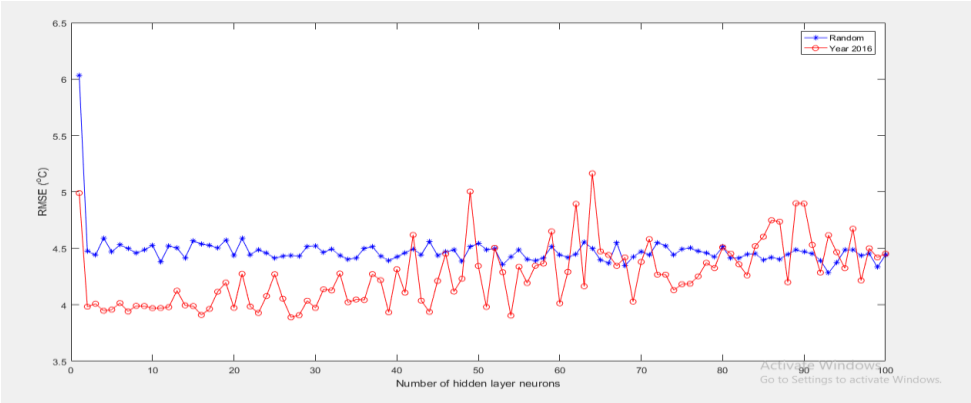

***Fig 9: RMSE** vs number of hidden layer neurons*

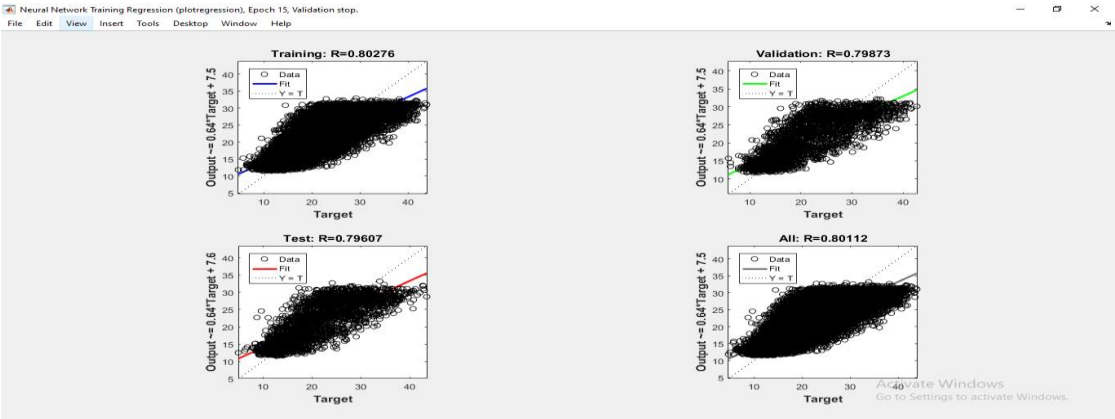

***Fig. 10:** Regression analysis of the system*

The RMSE values obtained for the year 2016 are indirectly the predicted values of the daily temperature. Since the values are present in the hidden neurons, the x axis represents the number of hidden neurons holding these values. A gradient is the direction and magnitude calculated in the neural network which is used to determine the direction in which the neurons tend to link each other. The graph in the second figure analyses the connection of neurons for 15 epochs , which results in the value of 0.86007. MU is the gain obtained in the hessian matrix, which is generally berween 0 and 1, and here it is 0.001 at epoch 15. The third graph in the picture is the validation check graph, which tells us how many checks are done in 15 epochs, including the failure of these checks. If a few of them are zero, then the system is termed to be a stable system. The error histogram is used to give the analysis between the inputs, outputs, validation and testing. Here 20 bins are used to analyse the output, along with instances. The zero error line is procured in the histogram, which tells us that there is no error present in the prediction of these values. Finally the regression plots are plotted between the outputs and four parameters, mainly the training, test, validation and all parameters. Regression models select the prediction values using the independent variables. It is mostly used to understand the link between prediction and forecasting. These graphs informs us about the presence of all the inputs and outputs, and the line indicates the path of the predicted values in all the four graphs, where the hidden neurons are present.

V. CONCLUSION

Accuracy has been one of the most important criteria in designing and upgrading any kind of system, be it hardware or software. This neural networking system designed using the neural networking tool using MATLAB predicts the weather for the year 2016 given the inputs of daily temperatures from the years 1965 to 2014, of a particular region. According to the user requirement, a person can predict the temperatures of any year, be it 2019 or 2025, given the change in inputs. This model mainly focuses in swift and zero error prediction, which means that the predicted value is the most exact value which can be obtained. The applications of neural networks in prediction has long been successful, and weather prediction might be helpful both layman as well as scientists. This tool might be helpful even for general purposes. For example, a person who wants to travel next week to a particular place can rely on this model rather than other sources. Hence this methodology of using ANN to design a weather prediction system is by far a better option compared to other systems which are prevalent.

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