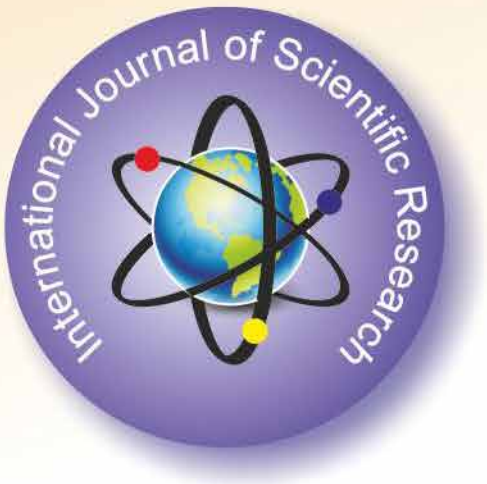
International Journal of Scientific Research

Indexed with International ISSN Directory, Paris

Volume 1 | Issue 2 | July 2012



ISSN No. 2277 – 8179

A Multi-Subject Journal

ISSN No. 2277 – 8179

International Journal of Scientific Research

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Volume : 1 | Issue : 2 | July 2012 • ISSN No 2277 - 8179

Research Paper

A Hybrid Neural Network Approach for Wind Speed Prediction

Engineering

KEYWORDS : MLP;Wind Speed Prediction; SOM

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ABSTRACT

This paper presents a hybrid neural network approach to predict wind speed automatically in renewable energy systems. Wind energy is one of the renewable energy systems with lowest cost of production of electricity with largest resources available. By the reason of the fluctuation and volatility in wind, the wind speed prediction provides the challenges in the stability of renewable energy system. The objective of this paper is to compute predicted wind speed based on hybrid technique which integrates a Self Organizing Map (SOM) and a Multi layer Perceptron (MLP) neural network. The experimental result shows that the proposed approach provides significant result of wind speed prediction with less error rates.

1. Introduction

The wind energy is an important potential renewable energy resource with lower cost of electricity production. With the accurate wind speed data, the wind farm operator can predict the power output. This is useful for power system planning, scheduling, and storage capacity optimization. Due to the random fluctuation characteristics of wind, the prediction results of wind power may change rapidly. Two critical issues in renewable energy are how to make wind energy cost effective and how to integrate wind energy into electricity grids. This increases the importance of the accurate wind speed prediction to assessment of wind energy and site selection of wind farm. To obtain proper and efficient wind power utilization, the wind speed prediction plays an important role in forecasting. To increase the accuracy of wind speed prediction, there are many approaches proposed, including physical method like numerical weather prediction, statistical method like ARMA model [1], the spatial correlation model and the artificial intelligence method, and so on.

During recent years, according to global environmental pollutions, a trend towards the sustainable energy and green power sources such as wind energy was largely increased. Wind energy is one of the economic renewable sources and a valuable supplement to conventional energy sources. One of the important problems in wide uses of wind power is difficulties of accurate wind speed prediction. It is not able to be stored because of wind is an intermittent, randomness, nonlinear nature. An accurate forecast allows grid operators to schedule an efficient generation to meet the demand of electrical customers. Artificial Neural Network (ANN) model is an efficient method for wind speed prediction. ANN exhibits the properties such as adaptability, capability of learning by previous examples, and ability to generalize. One of the most ANN model is the Multi Layer Perceptron network. Most of the available training methods for ANN focus on the adjustment of connection weights with in a topology.

Multi layer Perceptron is used successfully in many applications which include pattern classification, image processing, prediction etc. The back-propagation (BP) algorithm is one of the most popular methods for training MLP networks. The training process of MLP for prediction problem consists of two tasks, the first one is the selection of the appropriate architecture for the problem, and the second is the adjustment of connection weights of the network.

The Self Organizing Map (SOM) is known as an effective technique for the clustering of multi dimensional data. The SOM is a powerful tool for knowledge and visualization of high dimensional data. It is an unsupervised training method [2]. The objective of SOM is to maximize the degree of similarity of patterns within a cluster, minimize the similarity of patterns belonging to different clusters, and then to present the results in a lower dimensional space. The Kohonen algorithm is applied to unsupervised learning, where the target values are not specified. SOM is a topological structure made up of cluster units. The training algorithm builds in competition among neurons. Learning is restricted to neurons that are winners of the competition relating to the closeness of weights to the inputs.

In this paper, proposed hybrid neural network model which is the combination of SOM and MLP for better prediction system.SOM are unsupervised neural networks that build up an adequate representation of a high dimensional input space by means of a learning process into a lower dimensionality. SOM is used for clustering the input data and MLP is used for prediction applications.

II. LITERATURE REVIEW

Wind speed prediction is necessary as wind is an intermittent, randomness and nonlinear source of energy. Wind speed prediction from past observations has many applications in fields such as Target tracking, Rocket launch, Ship Navigation, Missile guidance, Satellite launch and Electrical power demand forecasting etc[3]. There are different types of neural network models available for wind speed prediction. Mainly wind speed forecasting models are MLP, Back Propagation Network (BPN), Radial Basis Function Network, Recurrent Neural Network and Hybrid Neural Network.

In 2005, Fonte P M et al [4] implemented neural network model which uses BPN for wind speed prediction. The achievement of mean squared error is 1.012 m/s. In 2006, Goncalo Xufre Silva et al [5] proposed a model which uses radial basis function (RBF) neural network for wind speed prediction and it compares more efficient than MLP model. The achievements are more efficient and feasible. In the same year Barbounis et al [6] proposed long term wind speed prediction using recurrent neural network. The key point is simple and stable. The achievements of result are predicted up to 72 hrs ahead. In 2009, Bei Chen et al [7] implemented model which uses OLS algorithm based on RBF. It predicts average hourly wind speed in 1 hr ahead. The achievements of results are revealing the effectiveness and accuracy of proposed approach. The above models are based on single type neural network model. In the same year LI Xingpei et al [8] proposed hybrid model which integrates genetic algorithm (GA) and Back Propagation. The key point is more effective. The achievements correlate that improved convergence rate, prediction precision, and prediction error and prediction time. In 2011, Shifin Guo et al [9] introduced wind speed prediction of genetic neural network based on rough set theory. The key point is improved speed, accuracy and feasible. The achievements are more reliable, overcome slow convergence speed and local minima. Umit Kemalettin Terzi et al [10] proposed new hybrid model which uses ANFIS and back propagation for wind speed forecasting. The key point is more accurate and flexible. It has 3% lower MSE than single ANN model. The achievements are predicted up to wind speed for long term.

According to the literature review, wind speed prediction is needed to be improving accuracy [12]. So hybrid neural network model is proposed. The single neural network model may lead to problems, Firstly mismatch between input and output

Volume : 1 | Issue : 2 | July 2012 • ISSN No 2277 - 8179

due to noise variation within the input. Secondly, it is difficult to get inner relation between input and output variable.

III. MULTILAYER PERCEPTRON (MLP) NEURAL NETWORK

The MLP is one of the most commonly used models in artificial neural networks. This type of neural network model is known as a supervised network because it requires a desired output in order to learn. It can be used for many applications such as classification problems, model construction, forecasting etc. For the forecasting problems, a back propagation (BP) algorithm is normally used to train the MLP Neural Network.

The performance of a neural network model is measured and evaluated using a test data. The test data should be distinct from the training data; otherwise testing will not reveal the true nature of the neural network adaptation and generalization ability. Once a neural network has been trained and tested, the performance is validated against an independent validation data.

A. *Architecture*

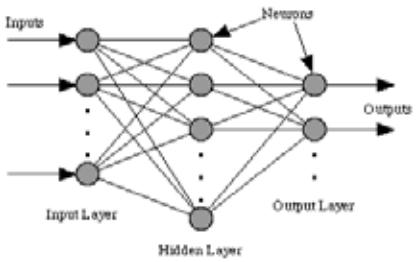


Figure1. MLP NN Architecture

It consists of 3 layers viz. an input layer, hidden and output layer. The output and hidden unit have bias which is always 1.The input layer is connected to hidden layer and the hidden layer is to output layer by weights. It has layers of processing elements, which make independent computations on data that it receives and passes the results to another layer and finally, determine the output from the network. Each processing element makes its computation based upon the weighted sum of its inputs. The first layer is always the input layer and the last layer is always the output layer. The layers placed between the first and the last layers are the hidden layers. The schematic diagram of MLP neural network is shown in Figure 1.

MLP Neural Network is a feed forward network formed by the non linear transformation. The MLP algorithm has two phases: The first phase (forward propagation) gives input information. From input layer, it calculates the actual output value of each unit layer by layer through hidden layer. If we are not getting the expected output in output layer we go for the second phase. In second phase, we calculate the difference of actual and expected output recursively, layer by layer. And we can adjust the weights based on this difference. The goal of training algorithm is to minimize global error. This algorithm calculates the error and distributes it backward from output to hidden and input nodes. This is done using steepest gradient descent rule.

B. Algorithm

The training of MLP is done in three stages, feed forward of inputs, calculation of error and updating of weights. Here MLP neural network is trained by using BP algorithm. The algorithm is as follows,

Step1: Initialize network weights using random values. Specify number of epochs, learning rate and momentum

Step2: Find output of network,

$Y=F(Yin)$ (1)

Where Yin is net input

Step3: Compute error, $e= (t-Y) F'(Yin)$, t is target vector (2)

Step4: Update weights,

$Wjk(new) = Wjk(old) + \Delta Wjk$ (3)

$\Delta Wjk = \alpha^* e^* Zj$, where α is learning rate, Zj is output of hidden neuron in sigmoid activation and error. The momentum is standard technique i.e. used to speed up convergence and maintain generalization performance. Adding of momentum in BPA is in order to reduce oscillation. The concept of momentum is that previous changes in the weights should influence the current direction of movement in weight space. This concept is implemented by the weight updation rule:

$Wjk(new) = Wjk(old) + \Delta Wjk(t+1)$ (4)

Where $\Delta Wjk(t+1) = \alpha^* e^* Zj + \eta [Wjk(t) - Wjk(t-1)]$, where α is learning rate and Zj is output of hidden neurons apply sigmoid activation.

IV. SELF ORGANIZING MAPS

Self organizing map is a data visualization technique invented by Prof. Teuvo Kohonen in 1972. The SOM is a popular tool that maps high dimensional space into a small number of dimensions by placing similar elements close together, forming clusters [11]. When the learning is based only upon the input data and is independent of desired output data, no error is calculated during the training of the network. This network is learning in unsupervised method. The objective of SOM is to maximize the degree of similarity of patterns within a cluster, minimize the similarity of patterns belonging to different clusters, and then present the results in a lower dimensional space. Such self organizing networks can be used for compressing, clustering, quantizing, classifying, or mapping input data. The back propagation neural networks have more than two layers (at least one hidden layer), and the Kohonen networks have only two layers (no hidden layers).When the network has adapted, the output layer processing elements represent clusters of the input pattern vectors.

A. Architecture

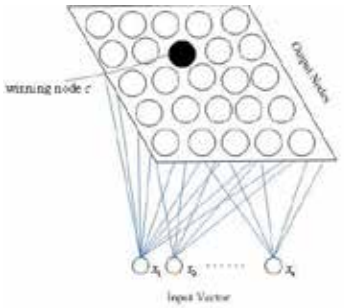


Figure2. SOM Architecture

The basic architecture of SOM is shown in figure 2. It consists of input and output node. Each of the input nodes is connected to each map node. None of the map nodes is interconnected. Weight connections between an input neuron and a neuron of the competitive layer are referred to as the reference vector in the input space. Only one unit is chosen to respond i.e. winner. The output unit is as cluster. The input vector (X1, X2 ……Xn) maps onto the best matching (winning) node c, based on the largest similarity or the smallest distance. The distance is calculated by Euclidean distance between input vector and weight vector. During training, net determines the output i.e. best match for current input .The weight vector for winner is then adjusted with network's learning algorithm. By assigning each input vector to the neuron with nearest feature vectors, the SOM is able to divide the input space into regions (clusters) with common nearest feature vectors.

B. Algorithm

The basic SOM algorithm is iterative. Each neuron i has an n dimensional feature vector wi = [wi1... wid]. At each training step

t, a sample data vector x (t) is randomly chosen for the training set. Distance between x (t) and all feature vectors are computed. The winning neuron is the neuron with the feature vector closest to x (t). A set of neighboring nodes of the winning node is denoted as Nc. We define ic (t) as the neighborhood kernel function around the winning neuron c at time t. The neighborhood kernel function is a non increasing function of time and of the distance of neuron i from the winning neuron c.

The algorithm of the SOM is as follows:

Step1: Initialization phase- Initialize the network weights using random values. Specify number of epochs, learning rate and neighborhood size etc.

Step2: Data normalization- For a better identification of the groups, the data have to be normalized. The data vector is normalized to lie in the interval [0, 1]. This means that the minimum value for each parameter in the dataset is 0 and the maximum value for each parameter is 1.

Step3: SOM Training- Select an input vector x from the data set randomly. Find winner using Euclidean distance method, is found from the map by the following ,

$\|x - mik\| = \min (\|x - mik\|)$ (5)

Where, mi is the reference vector associated with the unit i.

Step4: Updating Step- Update the weights within the neighborhood of node using the standard update rule:

$mi (t + 1) = mi(t) + \eta * [x(t) - mi(t)], i \in Nc(t)\ mi(t)$ (6)

where, t is the time constant. x(t) is an input vector randomly drawn from the input data set at time and η is the learning rate at time t. Nc(t) is the neighborhood set for the winner c.

De normalization is the reverse of the normalization procedure. The network typically produces output values in a limited range defined by the logistic or other activation function. These values bear little resemblance to the real world values of the application environment, and steps should be taken to de normalize the data back to the original data domain.

V. HYBRID COMPUTING MODEL

The proposed hybrid computing model is a combination of SOM and MLP. This is to realize for much better prediction system. SOM can be used for classification of data before the starting of the prediction. MLP is used for predictor. The objective of hybrid model is to benefit from the advantages of each model and to obtain globally optimal forecasting performance.

A. Architecture

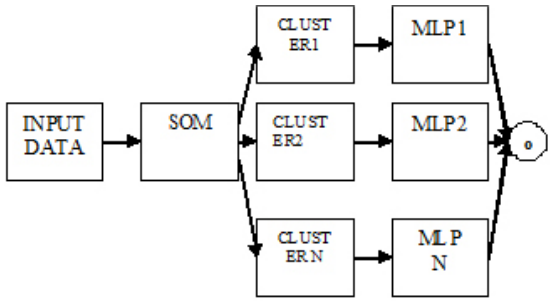


Figure3. Hybrid NN (SOM_ MLP) Architecture

The hybrid model architecture includes self organizing map and multi layer perceptron NN. Multi layer Perceptron is the most commonly used type of artificial neural networks. The non stationary character also indicates that the dynamic behaviors during different periods are dissimilar, which will results in the variations of dependency between input and output vectors. Therefore, many single forecasting models always lead to the following problems: initially, there is a mismatch between input and output spaces because of noise variations within input space, and secondly, it is difficult to get the inner relation between input and output variables. To improve the accuracy of forecasting, this hybrid model has been proposed [13].

The architecture of hybrid neural network model is shown in figure 3. Initially the partition of all the input data into similar subgroups and then use MLP model to produce forecasting results on all partitioned groups separately. Let the number of nodes of SOM net be K. So there are K MLP networks, each of receive the inputs.

B. Methodology

Step 1

Data Collection: - The wind data and related parameter values are collected from the wind farms. Here temperature, humidity, wind gust and past wind speed have been used as an input and predicted wind speed as an output to train an neural network in prediction applications.

Step 2

Data Normalization: - The input data are normalized, in the range of [0, 1] .The normalization is to eliminate the situation where some variables are given values with great impact on clustering than others.

Data normalized = Data (actual) - Data (min) / Data (max) –Data (min)

Step 3

Training SOM: - Set up the parameters including learning rate, epoch and dimensions and so forth. The training can be learned from the past data after normalization. Once the training is stopped, SOM partitioned the input data into clusters. The cluster outputs are generated.

Step 4

Training/Testing MLP: - Let the number of clusters be 'K'. So there are 'K' MLP networks, each receives inputs. Each MLP can be trained from past input data. Apply testing data to evaluate the performance of the trained network.

Step 5

Merge SOM and MLP: - The product of self organizing map output and multilayer perceptron output are computed. Since only one SOM output will be one and others will be zero. The only one MLP output will be pass to output layer. The output in output layer is the predicted wind speed.

Step 6

Data de normalization:-The output is carried out after normalization. Finally, the wind speed is predicted which is the output of the proposed hybrid model.

VI. EXPERIMENTAL RESULTS

The experiments were carried out to test performance of hybrid NN model in comparison with that of conventional MLP neural network. SOM divides the input data into clusters, in order to improve the accuracy of forecasting. Each cluster has MLP stages. The product of each MLP with SOM output is found to produce the predicted output. The RMSE value of hybrid computing model is less than conventional MLP neural network. ANN learns these data, and simulates wind speed in an advance. All the simulation results were generated using the MATLAB (version7.11).

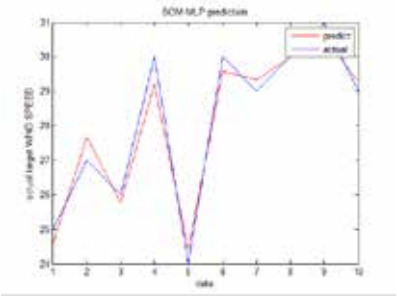


Figure4. Actual/ Predicted output waveform

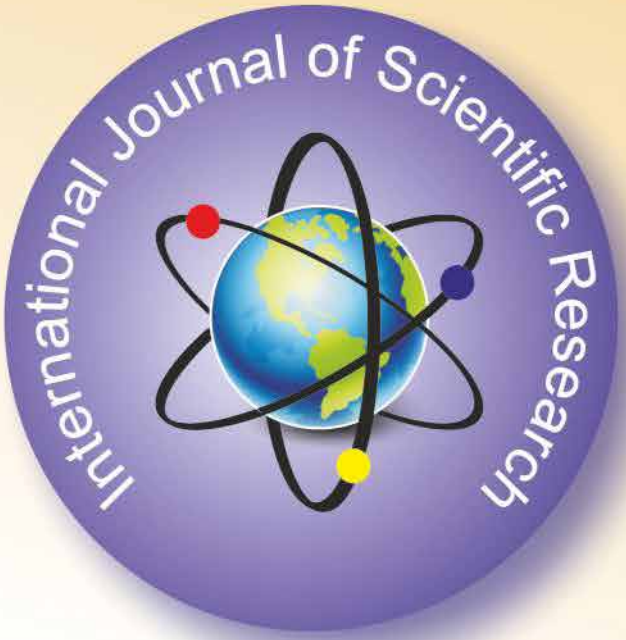
The Figure 4 shows the comparison between actual and predicted wind speed. The prediction error is noted. The performance of conventional MLP neural network and hybrid neural network model are identified by root means square method. The hybrid model was an effective, accurate than the other models. The RMSE of conventional MLP is 0.231 and hybrid neural network model is 0.13.

VII. CONCLUSION

The paper aimed at implementing the proposed hybrid neural network model for wind speed prediction. The hybrid approach presents best performance as compared to other neural network models. Each network is trained and tested using meteorological data. An experimental result shows that hybrid model outperforms the best agreement with lower error rates. In future research, we can improve the performance of network if we are implementing this using fuzzy neural network.

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