Wind Speed Prediction using Neural Network

Nand Kumar, Gurpreet Kaur, Aditi
(Delhi Technological University, Delhi, India)
Email: nandkumar@dce.ac.in

Abstract: The wind energy generation has been increasing rapidly in the past few years, making it imperative to know about the variables and the problems involved beforehand. The wind speed is a random variable and it depends on various atmospheric factors. This paper introduces a method to predict the wind speed effectively by making use of the algorithms of Artificial Neural Networks (ANN) and Support Vector Machine (SVM) in MATLAB. Data from Galicia, Spain was used to prepare valid dataset to train the neural network and a complex-valued neural network has been applied to build a model to predict wind speed. The results of the model show that the predicted data is close to the actual wind data available.

Keywords: Wind Power, Wind Speed, Artificial Neural Networks, Green Energy, Support Vector Machines (SVM).

I. INTRODUCTION

Wind is a form of green energy. Wind is caused because of non-uniform heating of earth’s surface. Different geographical aspects play an important role in determining the wind speed patterns. Wind flow is used to drive the wind turbines leading to the production of clean energy.

Wind is a clean form of energy but its regulation poses an insuperable problem before the energy engineers. The involvement of all the variables makes it almost impossible to predict wind speeds using simple methods or techniques. If the total output of a wind power plant (WPP) can be predicted with high accuracy, more useful information can be provided to the power companies to help in scheduling power generation. Thus allowing efficient use of Wind energy. Different methods have been adopted in the past to measure and predict the wind speed including statistical and physical methods which include the positioning of sensors and manual calculations based on the data obtained from different sensors positioned at numerous locations. The quality of hardware, accuracy of calculation, computation time delays and sampling rates define the efficacy of the final result. Also the computations cannot always be infallible. Therefore, better results demand for a better prediction system and mostly on the data already made available. This paper makes use of a technique known as Artificial Neural Networks to predict the trends in wind speed by making use of the historical data which is already available.

A number of studies have already been conducted in the past two decades in the area of forecasting green energy. Studies in the past shows conventional methods in forecasting. Later research in area of forecasting include machine learning, neural networks and support vector machine by train the network followed by prediction of green energy. Some of the earlier studies are given below:

In 1959, Bernard Widrow and Marcian Hoff of Stanford developed models they called ADALINE and MADALINE. These models were named for their use of Multiple ADaptive LINear Elements. MADALINE was the first neural network to be applied to a real world problem. It is an adaptive filter which eliminates echoes on phone lines. This neural network is still in commercial use. Unfortunately, these earlier successes caused people to exaggerate the potential of Neural Networks, particularly in light of the limitation in the electronics then available. This excessive hype, which flowed out of the academic and technical worlds, infected the general literature of the time. Disappointment set in as promises were unfilled. Also, a fear set in as writers began to ponder what effect “thinking machines” would have on man. Asimov’s series on robots revealed the effects on man’s morals and values when machines where capable of doing all of mankind’s work. Other writers created more sinister computers, such as HAL from the movie 2001. These fears, combined with unfulfilled, outrageous claims, caused respected voices to criticise the neural network research. The result was to halt much of the funding. This period of stunted growth lasted through 1981.

In 1982, interest in the field was renewed. John Hopfield of Caltech presented a paper to the National Academy of Sciences. His approach was to create more useful machines by using bidirectional lines. Previously, the connections between neurons were only one way. That same year, Reilly and Cooper used a “Hybrid network” with multiple layers, each layer using a different problem-solving strategy. Also in 1982, there was a joint US-Japan conference on Cooperative/Competitive Neural Networks. Japan announced
In 1986, with multiple layered neural networks in the news, the problem was how to extend the Widrow-Hoff rule to multiple layers. Three independent groups of researchers, one of which included David Rumelhart, a former member of Stanford's psychology department, came up with similar ideas which are now called back propagation networks because it distributes pattern recognition errors throughout the network. Hybrid networks used just two layers, these back-propagation networks use many. The result is that back-propagation networks are "slow learners," needing possibly thousands of iterations to learn.

In 1962 Rosenblatt (Rosenblatt, 1962) explored a different kind of learning machines: perceptrons or neural networks. The perceptron consists of connected neurons, where each neuron implements a separating hyperplane, so the perceptron as a whole implements a piecewise linear separating surface. See Fig. 1. No algorithm that minimizes the error on a set of vectors by adjusting all the weights of the network was found in Rosenblatt's time, and Rosenblatt suggested a scheme where only the weights of the output unit were adaptive. According to the fixed setting of the other weights the input vectors are non-linearly transformed into the feature space, Z, of the last layer of units. In this space a linear decision function is constructed.

An algorithm that allows for all weights of the neural network to adapt in order locally to minimize the error on a set of vectors belonging to a pattern recognition problem was found in 1986 (Rumelhart, Hinton & Williams, 1986,1987; Parker, 1985; LeCun, 1985) when the backpropagation algorithm was discovered. The solution involves a slight modification of the mathematical model of neurons. Therefore, neural networks implement "piece-wise linear type" decision functions. In this article we construct a new type of learning machine, the so-called support-vector network. The support-vector network implements the following idea: it maps the input vectors into some high dimensional feature space Z through some non-linear mapping chosen a priori. In this space a linear decision surface is constructed with special properties that ensure high generalization ability of the network.

Warren Sturgis McCulloch (November 16, 1898 – September 24, 1969) was an American neurophysiologist and cybernetician, known for his work on the foundation for certain brain theories and his contribution to the cybernetics movement. In the 1943 paper they attempted to demonstrate that a Turing machine program could be implemented in a finite network of formal neurons (in the event, the Turing Machine contains their model of the brain, but the converse is not true), that the neuron was the base logic unit of the brain. In the 1947 paper they offered approaches to designing "nervous nets" to recognize visual inputs despite changes in orientation or size. From 1952 he worked at the Research Laboratory of Electronics at MIT, working primarily on neural network modelling. His team examined the visual system of the frog in consideration of McCulloch's 1947 paper, discovering that the eye provides the brain with information that is already, to a degree, organized and interpreted, instead of simply transmitting an image.

II. RESEARCH METHODOLOGY

Artificial Neural Networks (ANN)

It is the method that consists of networks of many simple processors (units) operating in parallel, each possibly having a small amount of local memory. A multilayer perceptron neural network, with feedforward architecture with three layers of units is used due to its status and capacity to solve large amount of problems. The algorithm used for the training is the well-known back-propagation method (Haykin, 2003). Fig 1 depicts the feed-forward neural network which is used. This neural network shows the first layer (layer A) and the second layer (layer B), which are called hidden layers. This network has one unit in the third layer (layer C), which is called the outputlayer. Each unit has an extra input that is assumed to have a constant value of one. The weight that modifies this extra input is called the bias. Data propagate along the connections in the direction from the network inputs to the network outputs, hence the term feed-forward (Negnevitsky, 2002).

Fig 1. Structure of a typical neural network

A key concept required for defining a linear classifier is the dot product between two vectors

\[ \langle w, x \rangle = \sum_{j=1}^{M} w_j x_j \]

also referred to as the inner product or scalar product. A linear classifier is based on a linear discriminant function of the form

\[ f(x) = \mathbf{w} \cdot \mathbf{x} + b. \]
The discriminant function $f(x)$ assigns a “score” for the input $x$, and is used to decide how to classify it. The vector $\mathbf{w}$ is known as the weight vector, and the scalar $b$ is called the bias. In two dimensions the points satisfying the equation $\mathbf{w} \cdot \mathbf{x} = 0$ correspond to a line through the origin, in three dimensions a plane and more generally a hyperplane. The hyperplane divides the space into two half spaces according to the sign of $f(x)$, which indicates the side of the hyperplane a point is located on the figure. If $f(x) > 0$, then one decides for the positive class, otherwise for the negative. The boundary between regions classified as positive and negative is called the decision boundary of the classifier.

III. RESULTS AND DISCUSSIONS

Results 1st - 7th January are shown in figures 3-4 and 1st - 7th July are shown in figures 5-6

1st-7th January

Fig 2.A typical Scatter Plot

Fig 3.Windspeed vs. Date
Fig 4. Scatter plot

1st - 7th July

Wind Speed

Fig 5. Windspeed vs. date

Fig 6. Scatter plot
The ANN toolbar used to train the network yielded better results on increasing the number of neurons present in the model. Also the more the number of samples of the given variables related to wind speed, the more accurate was the result obtained. In this paper the wind data over a period of two years was compiled and tested against the original and finally SVM classifier was used to predict the wind speed which was compared with the original data available.

The ANN toolbar used to train the network yielded better results on increasing the number of neurons present in the model. Also the more the number of samples of the given variables related to wind speed, the more accurate was the result obtained. In this paper the wind data over a period of two years was compiled and tested against the original and finally SVM classifier was used to predict the wind speed which was compared with the original data available.

![Fig 7. Scatter plot showing division of data on either sides of the hyper plane](image)

The separation achieved is good by the hyperplane that has the largest distance to the nearest training-data point of any class (so-called functional margin), the larger the margin the lower the generalization error of the classifier.

IV. CONCLUSIONS

This paper uses SVM and ANN toolbar for windspeed prediction. It compares the results from the network (trained using Neural Network) with original data over a period of two years. Smoother error in the predicted data was 1.2% and 3.2% for the periods 1st-7th January and 1st-7th July respectively. The findings of this paper indicate that the methods adopted to predict the speed of the wind produced desired results and that the error in the predictions was low.

REFERENCES


