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Short Term Wind Speed Forecasting with ANN in Batman, Turkey

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Introduction

Wind speed forecasting is necessary for power system because of the intermittence nature of wind. Accurate wind speed forecasting of wind farms can relieve or avoid the disadvantageous impact to the electric network. A lot of studies have been performed to develop the precision of wind speed prediction [1, 2]. The mathematical model of the human brain was tried to be obtained, inspired by its neurophysical structure; and with the consideration that in order to model the whole behavior of the brain the physical components had to be modeled correctly, various artificial cell and network models were developed. Thus, a new scientific field called Artificial Neural Networks, which is widely different from the algorithmic calculation methods of the computers used today, was born. Because of their structure, their difference in processing data and their fields of application, Artificial Neural Networks are used by many scientists from various disciplines ranging from engineering to medical sciences as an efficient method. ANN, compared to traditional methods, offers very efficient and different solution methods in the solution of complicated real world problems. It is a mathematical method that presents contemporary applications, which are pretty hard to predict and calculate, in terms of absolute solutions [3].

The ability to predict accurately the future is fundamental in the planning and decision making in any activity; the inherent nonlinear structure is useful to manage the complex relations in problems of diverse disciplines. Also, ANN has demonstrated high capacity in the modeling of time series for different applications. The models for wind forecasting and power generation are valuable support tools to support the operators of the General Directorate of Electrical Power Resources Survey and Development Administration (EIE). The measurements of the wind speed are generally reported in the form of time series (minutes, hours, months, etc.), which are adequate to use ANN for prediction purposes. Although in Batman, there is not any wind power installed and it is expected to set up in the next decade, the EIE have not yet a mathematical model in order to predict accurately the short term wind velocities to do an adequate electricity supply. Because of this, it is important to develop a model that can be used confidently for this purpose. Also the methodology showed in this work can be used to generate other models in different sites of Turkey and other countries [4].

In this paper, diverse configurations of ANN that have different number of neurons were generated and compared through error measures, guaranteeing the performance and accuracy of the chosen models. A model for every month of the year was developed. Four different configurations of ANN of two layers (with different number of neurons) were proven determining their statistical error in order to obtain the best model for every month. Finally the ANN model was evaluated for the forecasting using data not considered previously during their training stage. Because of the best configuration of the ANN consisting of forty neurons was always the same (with exception of the weights) for the 12 months, in this paper just the results for the month of January is presented.

Artificial neural networks

An Artificial Neural Network is shaped by structuring a foreseen number of artificial neural cells in a certain architecture in order to process data. This structure usually consists of a few layers, which are numbered. The first layer is the entry layer and is often not numbered. The reason for this layer to be excluded from enumeration is that the elements in the entry layer don't have weighting multipliers and activation functions and thus cannot perform any other process but data entry. The common name of the other intermediate layers, which can differ in number according to preference, is hidden layers. The exit layer is the last layer. The Artificial Neural Network model with backpropagation is the most widely used multilayered prediction model. Such a network including three layers of perceptrons is shown in Figure 2. By the algorithmic approach known as Levenberg-Marquardt back propagation algorithm, the error is decreased repeatedly. Some ANN models employ supervisory training while others are referred to as none-supervisory or self-organizing training. However, the vast majority of ANN models use supervisory training. The training phase may consume a lot of time. In the supervisory training, the actual output of ANN is compared with the desired output [5, 6]. The training set consists of presenting input and output data to the network. The network adjusts the weighting coefficients, which usually begin with random set, so that the next iteration will produce a closer match between the desired and the actual output. The training method tries to minimize the current errors for all processing elements. This global error reduction is created over time by continuously modifying the weighting coefficients until the ANN reaches the user defined performance level. This level signifies that the network has achieved the desired statistical accuracy for a given sequence of inputs. When no further training is necessary, the weighting coefficients are frozen for the application. After a supervisory network performs well on the training data, then it is important to see what it can do with data it has not seen before. If a system does not give reasonable outputs for this test set, the training period is not over. Indeed, this testing is critical to insure that the network has not simply memorized a given set of data, but has learned the general patterns involved within an application [7].

Time series model

Time series are strings formed by sequencing the observation values of an event according to time. Time series analysis is a method that aims at modeling the stochastic process that yields the structure of an observed series of an event that is observed in certain intervals, and making future predictions via the observation values belonging to past intervals. Fig. 1 shows the time series used in the models which consists of 744 data in total, corresponding to daily mean data for each of the 31 days of the last January. The training set with 670 data was used for the models' training and the prediction set consisting of 37 data as validation and 37 data as test were used to verify their accuracy during the prediction stage [4, 5, 8].

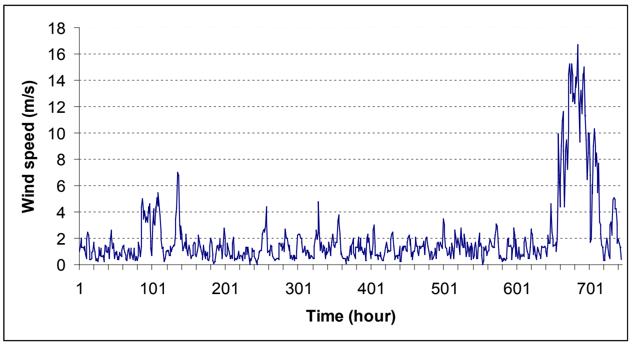

Fig. 1. January mean hourly values in Batman

Errors and Performance of the Models

ANN's, using previous samples, form a relationship between input variables and predicted variables by determining weights. In other words, ANN's are trained. Once trained, an ANN can work with new data and produce predictions. The performance of a network is measured by the intended signal and error criterion. The output of the network is compared to the intended output to obtain the margin of error. An algorithm called backpropagation is used to calibrate the weights in order to reduce the margin of error. The network is trained by repeating this process a number of times. The goal of the training process is to reach the optimum solution in terms of performance measurements.

Some error analyses have to be performed in order to be able to evaluate the performance and prediction results of the model more correctly. The mean squared error (MSE) and mean absolute error (MAE) are among those error values.

If it is the actual observation for a time period t and F_t is the forecast for the same period, then the error is defined as

$$e_t = y_t - F_t . \quad (1)$$

The standard statistical error measures can be defined as

$$MSE = \frac{1}{n}\sum_{t=1}^{n} e_t^2 \quad (2)$$

and the mean absolute error as

$$MAE = \frac{1}{n}\sum_{t=1}^{n} |e_t| , \quad (3)$$

where n is the number of periods of time [9].

Proposed ANN models

The number of layers and the number of processing elements per layer are important decisions for selecting the ANN architecture. Choosing these parameters to a feed forward back propagation topology is the art of the ANN designer. There is no quantifiable, best answer to the layout of the network for any particular application. There are only general rules picked up over time and followed by most researchers and engineers applying this architecture to their problems. The first rule states that if the complexity in the relationship between the input data and the desired output increases, then the number of the processing elements in the hidden layer should also increase. The second rule says that if the process being modeled is separable into multiple stages, then additional hidden layer(s) may be required. The result of the tests has showed that the optimal number of neurons in the hidden layer can be chosen as 40 also, the activation function has been chosen as a hyperbolic tangent sigmoid function for all of the layers [7]. ANN simulators have been trained through the 25, 10, 33, 26 epochs with 10, 20, 30, 40 neurons respectively. The training process has been stopped when the error has become stable. Variation of the total absolute error through the epochs is for ANN 4 (with 40 numbers of neurons) shown in Figure 3 [10].

In order to use the ANN simulator for any application, first the number of neurons in the layers, type of activation function (purelin, tansig, logsig), the number of patterns, and the training rate must be chosen. Normalization of data is a process of scaling the numbers in a data set to improve the accuracy of the subsequent numeric computations and is an important stage for training of the ANN. Normalization also helps in shaping the activation function. For this reason, [+1, -1] normalization function has been used [11, 12]. The designed models to be analyzed are the following ones:

1. Model 1 (1ann10): Eleven input neurons (previous values of daily wind speed, air pressure, air temperature, soil temperature and relative humidity), ten neurons in the hidden layer, and one output neuron (current value of wind speed).
2. Model 2 (2ann20): Eleven input neurons (previous values of daily wind speed, air pressure, air temperature, soil temperature and relative humidity), twenty neurons in the hidden layer, and one output neuron (current value of wind speed).
3. Model 3 (3ann30): Eleven input neurons (previous values of daily wind speed, air pressure, air temperature, soil temperature and relative humidity), thirty neurons in the hidden layer, and one output neuron (current value of wind speed).
4. Model 4 (4ann40): Eleven input neurons (previous values of daily wind speed, air pressure, air temperature, soil temperature and relative humidity), forty neurons in the hidden layer, and one output neuron (current value of wind speed).

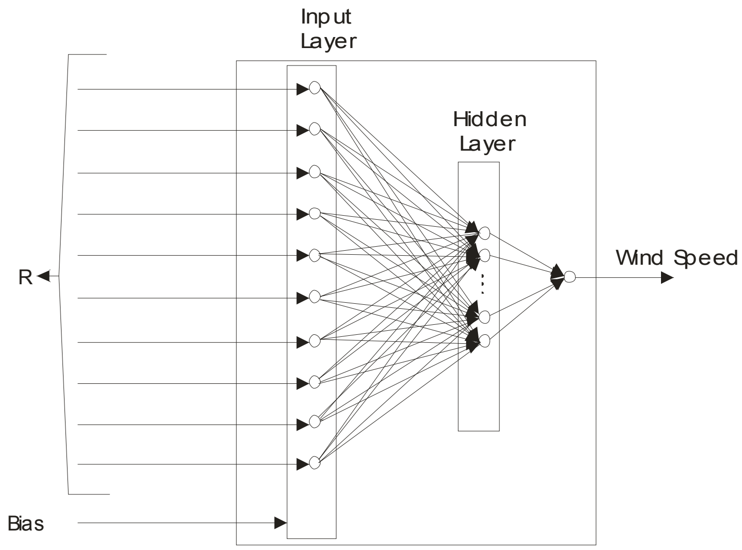

Fig. 2. Multilayers feed forward network

Results

Mean squared error is the average squared difference between outputs and targets. Lower values are better. Zero means no error. Fig. 3 shows the evolution of the minimum error for Model 4. In this figure it can be seen how the error decreases rapidly for training, testing and validation and then remains almost constant from the iteration 25.

Fig. 4, Fig. 5, Fig. 6 and Fig. 7 compare the results obtained using the model 1, 2, 3, and 4 respectively with the real data. It can be seen how the model predicts in a reasonable way the randomness of the data. Comparison of the models for mean squared error and regression values can be observed clearly in Table 1.

Table 1. Mean squared error and regression values for the four models

	Training		Validation		Testing	
Models	**MSE**	**Regression**	**MSE**	**Regression**	**MSE**	**Regression**
1ANN10	0.936396	0.931481	0.993366	0.923701	2.02594	0.915938
2ANN20	0.803162	0.945149	0.484204	0.942277	1.05979	0.943718
3ANN30	0.376913	0.974638	0.205948	0.966457	0.771376	0.954503
4ANN40	0.311136	0.978094	0.657963	0.959728	0.596061	0.969927

In this table it can be seen that the best model is the last one, consisting of two layers with four input neurons and one output neuron and eighty neurons in the hidden layer. The other models predict the behavior of the wind but with a gap at high velocities [13]. Also Table 1 shows the mean squared error and regression values for the four models. As it was expected the lowest statistical errors were obtained with the model 4. Once the best model was obtained to reproduce the real data, it is important to verify its accuracy utilizing the data outside the sample. This means to use the last 74 data not considered during the training of the ANN, corresponding to the month of January 2008 [14].

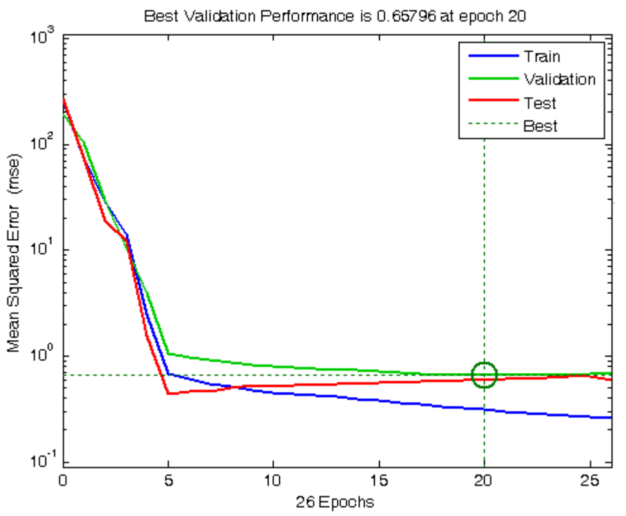

Fig. 3. Variation of the total absolute error through the epochs for Model 4

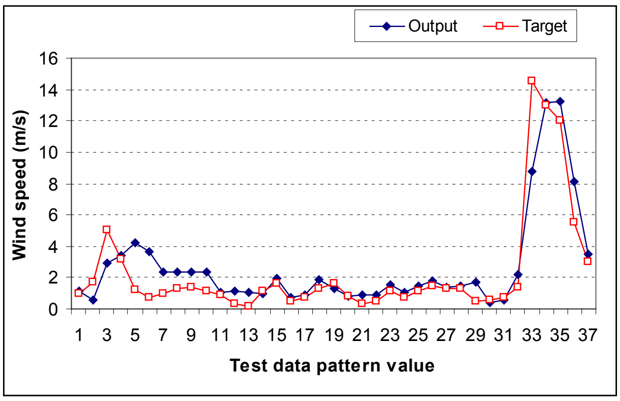

Fig. 4. Comparison of the real data with the results obtained using the model 1

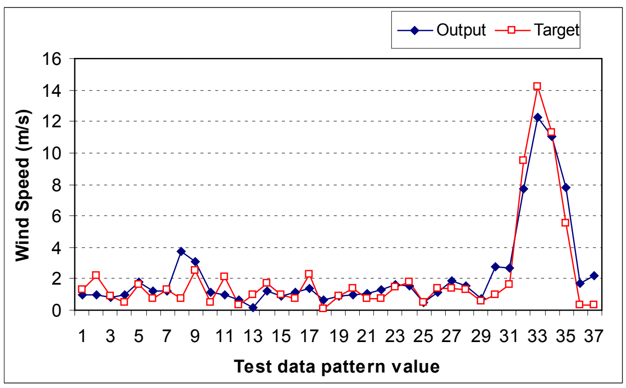

Fig. 5. Comparison of the real data with the results obtained using the model 2

When we examine the results of the ANN model, we see that the results derived from the analysis are quite succesful. Examining Fig. 4, Fig. 5, Fig. 6 and Fig. 7, we see that the actual data and the ANN prediction results are highly compatible. This, in turn, can be shown as an evidence of the satisfactory success of short term wind speed prediction via ANN.

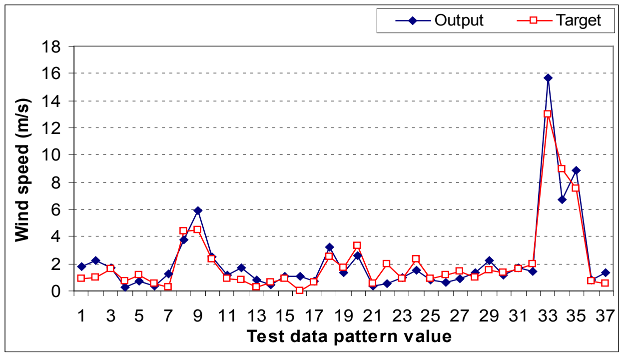

Fig. 6. Comparison of the real data with the results obtained using the model 3

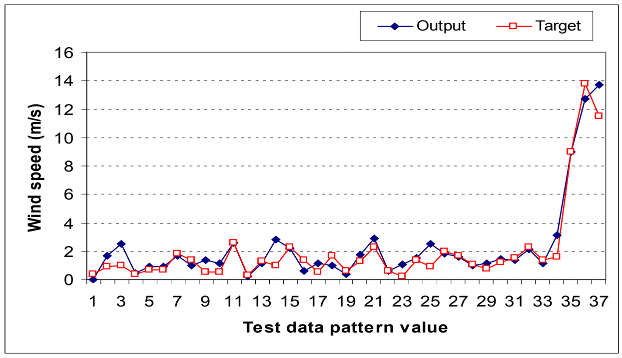

Fig. 7. Comparison of the real data with the results obtained using the model 4

Conclusions

In the test, an unknown input pattern has been presented to the ANN, and the output has been calculated. Linear regression between the ANN output and target is performed. In the particular case of Batman, it was decided to begin the analysis with a model with three neurons, according to the recommendations of diverse authors; nevertheless, the model with forty neurons was the best for both the training and forecasting stages, which reflect the persistency of the wind in the site. The selection of the suitable model using ANN implies a process of careful analysis that depends on the characteristics of the problem; for short term wind speed forecasting this technique responds of a satisfactory way to the necessities of precision and accuracy required to support the operators of the Electric Utility Control Centre.

As a result, this forecasting model, which was developed for the Batman area in the Southeastern Anatolia Region of Turkey, can be considered a beginning for the research and efforts for the wind stations which will possibly be built in Batman.

Acknowledgments

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T. Ç. Akinci. Short Term Wind Speed Forecasting with ANN in Batman, Turkey // Electronics and Electrical Engineering. – Kaunas: Technologija, 2011. – No. 1(107). – P. 41–45.

In this paper, Artificial Neural Network (ANN) technique has been used for the short term estimation of wind speed in the region of Batman, Turkey. The data were collected by the Turkish State Meteorological Service (TSMS) during ten years through a network of measurement stations located in the place of interest. Different ANN models has been developed for the short term wind speed forecasting in Batman, Turkey, using data measurements of 10 year obtained from the Turkish State Meteorological Service. First a model with ten neurons in hidden layer was chosen, the results were not sufficiently satisfactory. Other three models were developed, consisting of twenty neurons, thirty neurons and forty neurons in the hidden layers. The model of forty neurons was the best for the short term wind speed forecasting, with mean squared error and regression values of 0.311136 and 0.978094 for training respectively. The developed model for short term wind speed forecasting showed a very good accuracy to be used by the General Directorate of Electrical Power Resources Survey and Development Administration (EIE) in Batman, Turkey for the energy supply. Ill. 7, bibl. 14, tabl. 1 (in English; abstracts in English and Lithuanian).

T. Ç. Akinci. Trumpalaikio vėjo greičio prognozavimas taikant dirbtinio intelekto neuroninius tinklus // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2011. – Nr. 1(107). – P. 41–45.

Aprašytas Batmane, Turkijoje atliktas trumpalaikio vėjo greičio prognozavimas taikant dirbtinio intelekto neuroninius tinklus. Informacija apie tos vietovės metrologinius parametrus yra surinkta taikant metrologines stoteles ir saugoma Turkijos metrologijos institute. Pasirinktas imties laikotarpis – 10 m. Pagal sukauptus duomenis sukurta keletas modelių taikant dirbtinio intelekto neuroninius tinklus. Pirmuoju atveju buvo pasirinktas modelis su dešimčia įvairiuose sluoksniuose paslėptų neuronų. Gauti rezultatai buvo prasti. Kiti trys modeliai buvo sudaryti iš dvidešimties, trisdešimties ir keturiasdešimties neuronų, paslėptų įvairiuose sluoksniuose. Naudojant ketvirtąjį modelį, gauti geriausi rezultatai. Vidutinė kvadratinė paklaida – 0,311136. Toks modelis gali būti naudojamas alternatyviai elektros energijai prognozuoti. Il. 7, bibl. 14, lent. 1 (anglų kalba; santraukos anglų ir lietuvių k.).