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K-NN Based Wind Speed Prediction for Energy Conversion and Management

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Abstract--Electricity plays an important role in human civilization. Every aspect of human life and its well being depends on the energy conversion into electricity and utilize it for optimal performance in all kinds of industries. Wind energy is one such important energy being used in the world for producing electricity. However, wind speed is not predictable and thus the wind energy conversion is not straightaway schedulable. In this context, it is a challenging problem to predict wind speed accurately. It is very important for power generation and operations. Recently Yesilbudak et al. proposed a method that predicts wind speed using k-nearest neighbor classification algorithm. Various distance measures are used to achieve wind speed prediction. In this paper we implement a prototype application using Java programming language that will take pre-recorded datasets and performs the prediction of wind speed for a short term. The empirical results are encouraging.

Index Terms – Energy conversion, wind speed, k-NN classification

I. INTRODUCTION

Wind energy plays an important role in producing electricity. It has become a dependable source of power energy in the world. Its production has been increased from 6.1 GW in 1996 to around 200 GW in 2010 [1], [2]. Wind turbines are used for generating wind power. Wind turbines have variable and intermittent structures as the wind speed is stochastic in nature [3]. The dispatcher is supposed to predict wind speed in order to estimate the operations required. Wind speed is very important parameter in energy conversion and management. There are many techniques that came into existence in the real world. The methods can be categorized into many types. They include physical models, spatial correlation models, conventional statistical model and artificial intelligence (AI) models. Physical data like roughness, obstacles, pressure, orography and temperature are used by physical models. They are also used for weather research forecast. Other applications of them include ETA model, Mesoscale Model 5, COSMO and High Resolution Model. Spatial correlation models consider the wind speed as time series data and predict the wind speed in terms of sites and neighboring sites. Artifical intelligence is explored in [4], [5], and [6] for implementing wind prediction. Conventional statistical methods on the other hand focus on mathematical model to express the problem and solution. They provide better results when compared with the other models. Some of the examples for conventional statistical methods include Kalman filtering, Markov Chain Model, ARIMA models and autoregressive models.

Figure 1 – Wind speed effect

As can be seen in Figure 1, it is evident that there is wind that comes in various speeds. The prediction of it is important and the wind power can be used to convert into electricity. The aim of the paper is to predict wind speed using direction of wind, relative humidity, atmospheric pressure, and air temperature using k-NN classification algorithm. Many distance measures are used for the prediction purposes. A prototype application is built to simulate the results using real world datasets. The research results reveal many useful and reasonable inferences that are part of the wind prediction. The distance metrics played an important role in achieving this. The remainder of this paper is structured as follows. Section II reviews literature on prior work. Section III presents the proposed approach for wind speed prediction. Section IV presents experimental results while section V concludes the paper besides providing directions for future work.

II. RELATED WORKS

Wind speed prediction has been around for many years. Many researchers contributed to realize electricity generation from wind power. Latha et al. [7] presented a practical approach using data mining for weather forecasting. Similar approach is followed by McGovern in [8]. Kanth et al. [9] explored various means to nalyze dataset provided by Indian Government pertaining to weather. Li et al. [10] studied weather forecasting and storm detection in the wake of problems faced by USA every year through storms. Onwubolu et al. [11] proposed a self organizing data mining method for weather forecasting. Cortez and Morais [12] presented data mining approach for prediction of fire in forests. Olaiya [13] applied data mining techniques for studying climate changes and weather forecasting. Dutta and Tahbuilder [14] presented a data mining approach for prediction of rain fall. Jan et al. [15] used k-NN technique for inter-annual climate prediction. Kalyankar and Alaspurkar [16] applied data mining techniques for analyzing metrological data.

All the above studies are related to climate study and weather forecasting. However the focus of this paper is wind speed prediction for energy conversion.

There are many researchers that are related to this paper. They include weather research and forecast model (WRF), ETA model [17], ARMA models [18], [19], SVM [20], neuro-fuzzy inference models [21], [22], Kalman filtering [23], COSMO [24], MM5 [25], HRM [26], and m-means clustering model [27]. In this paper the focus was in k-NN classification model that considers various distance measures in order to predict wind speed accurately. This will pave way for energy conversion and management in the presence of uncertain wind speed.

III. PROPOSED METHODOLOGY

Data mining approach using k-NN classification is used for wind speed prediction. The k-NN classification is very important data mining technique that is used in many real world applications to predict uncertain things and estimate the parameters in order to help various aspects. For instance it can be used to predict weather forecasting which will help people take necessary steps to tide over the difficult situations that are encountered in case of storms, cyclones and so on. Manhattan and Minkowski distance metrics and Euclidean distance metric are used to have prediction accuracy. Pre-recorded datasets were collected from meteorological stations. The datasets are taken as multi-tupled inputs to the prediction technique for wind speed prediction. The prediction performance is evaluated using Normalized Root Mean Square Error (NRMSE), Mean Absolute Percentage Error (MAPE), and Mean Absolute Error (MAE). More details on the k-NN classification can be found in [28].

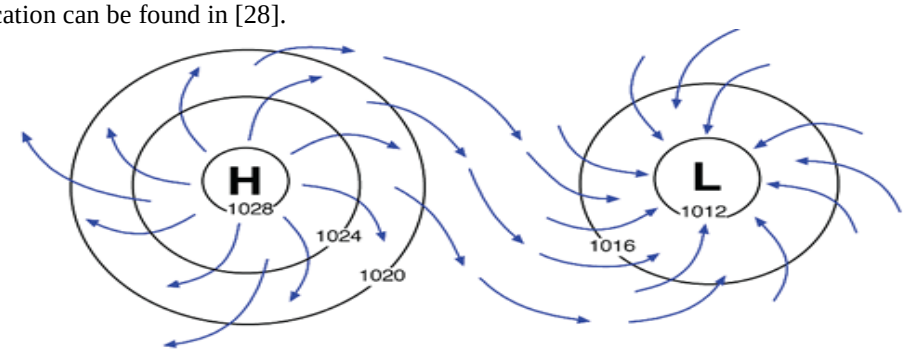

Figure 2 – Illustrates variations in wind speed

As can be seen in Figure 2, it is evident that the wind speed has variations and that needs to be predicted in order to have perfect mechanism to convert the wind power into electricity. In this paper the focus is on k-NN classification which takes datasets as input and generates prediction results. The overview of the methodology used in this paper for wind speed prediction is as presented in Figure 3.

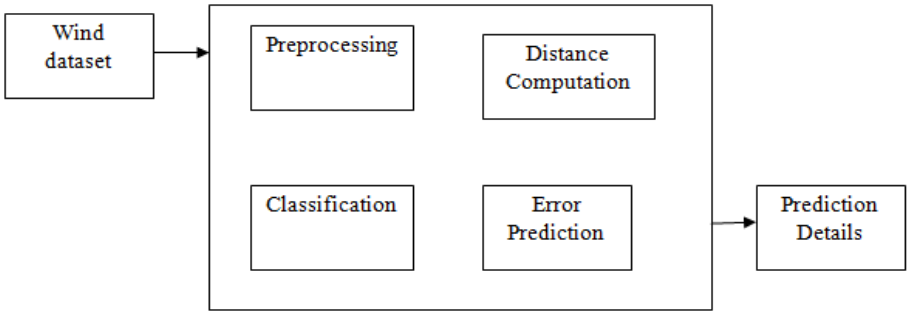

Figure 3 – Illustrates the phases in wind speed prediction

As can be seen in Figure 3, there are four phases in the prediction model. The first phase is preprocessing in which the selection of training dataset, test dataset, distance metrics and the value for k are taken into consideration. Afterwards distance calculation methods are invoked so as to know the distance dynamics for the given dataset. Afterwards, the k-NN classification method takes the distances into consideration for prediction of wind speed through the classification approach. Finally error estimation takes place for further optimization in order to improve the prediction performance. MAE and MAPE approaches are used for error prediction.

IV. PROTOTYPE AND EXPERIMENTAL RESULTS

We built a prototype application for demonstrating the proof of concept. Java programming language is used to build an application with GUI. The application provides intuitive interface that guides users to perform prediction of wind. The application takes datasets as input and generates prediction of wind speed in short period of time. Dataset is obviously a time-series dataset. k-NN algorithm is applied on the dataset for classification. The environment used for the experiments is a PC with 4 GB RAM, core 2 dual processor running Windows 7 operating system. The experimental results are presented here.

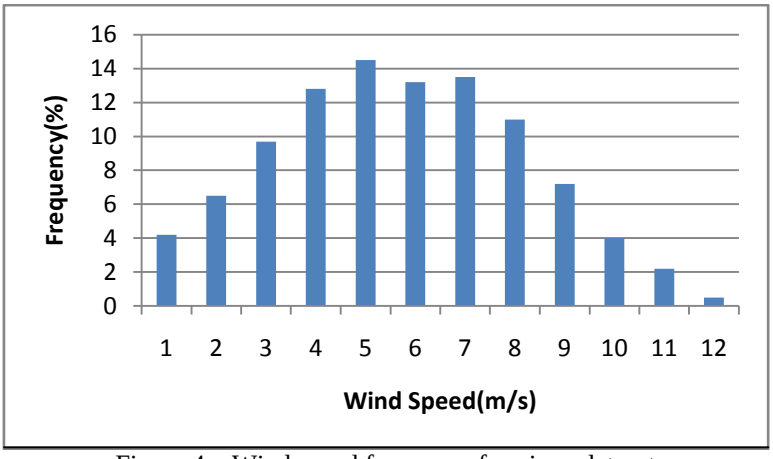

Figure 4 – Wind speed frequency for given dataset

As can be seen in Figure 4 it is evident that the results reveal the frequency of the wind based on the wind speed. The horizontal axis represents wind speed in milliseconds while the vertical axis represents frequency percentage. The results reveal the frequency dynamics with respect to different wind speeds. The parameters considered for experiments include humidity, air temperature and wind direction. Figure 5, 6 and 7 present wind speed prediction results.

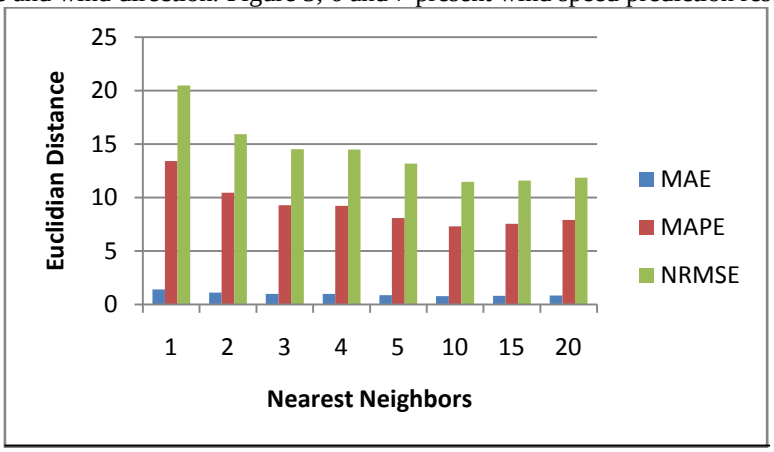

Figure 5 - Wind speed prediction results for wind direction

As shown in the above figure horizontal axis represents nearest neighbors while vertical axis represents Eculidian distance.

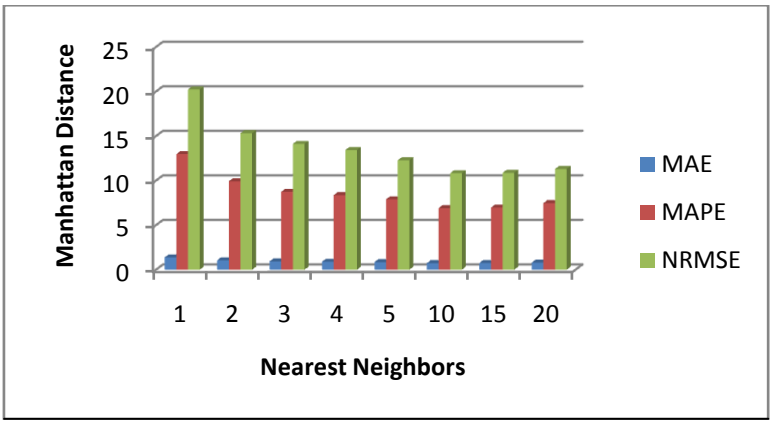

Figure 6 -- Wind speed prediction results for wind direction

As shown in the above figure horizontal axis represents nearest neighbors while vertical axis represents manhattan distance.

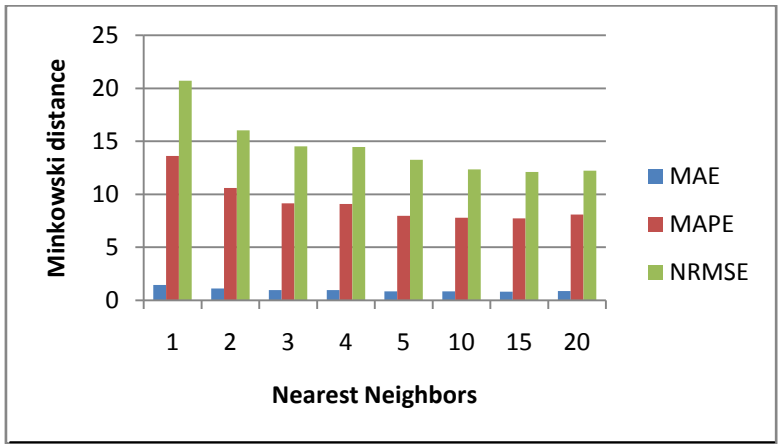

Figure 7--Wind speed prediction results for wind direction

As shown in the above figure horizontal axis represents nearest neighbors while vertical axis represents minkowski distance.

V. CONCLUSIONS AND FUTURE WORK

In this paper we studied the problem of wind speed prediction for the purpose of energy conversion and management. Dataset is taken from meteorological stations. The algorithm used to predict wind speed is k-NN classification, a data mining approach. Three distance metrics are used for best prediction of wind speed. They are Euclidean distance, Minkowski distance, and Manhattan distance. Three error prediction models are employed such as MAE, MAPE and MRMSE. The parameters used for experiments include atmospheric pressure, air temperature and wind direction. There are four phases in the algorithm. They are pre-processing, distance computation, classification and error prediction. With k-values differently taken, experiments are made with given parameters. We built a prototype application to demonstrate the proof of concept. The empirical results revealed that the proposed methodology was able to predict wind speed which can be used further to convert window energy into electricity. In future we focus on applying our method in real world scenarios.

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