A Bayesian short-term strategy for wind potential assessment

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Abstract
The economic profitability is strongly influenced not only by the wind speed, which is needed to define the turbine type to be installed, but also by its direction, which represents a dominant parameter in the wind farm layout design. Wind potential assessment from short (e.g., one-month) sample can be severely poor if performed when the wind is not blowing from the prevailing direction(s). This paper proposes a Bayesian approach in order to hasten directional data analysis collected from an Italian candidate site. In particular, the wind direction is grouped in 8 sectors and modelled with the multinomial distribution. The Dirichlet distribution is chosen as prior and is derived from historical data available at a neighboring survey station. In particular, the prior distribution elicitation is based on the Fisher’s angular-anchoring association between directional data with speed value greater than 4 m/s, which are collected simultaneously from the candidate site and the neighboring survey station. In expert opinion, such threshold value represents the least speed which is able to effectively activate turbines. Then, the Bayesian approach proposed in [1], which involves MCMC (Markov chain Monte Carlo) method, is opportunely adjusted in order to furnish the estimates of the wind speed distribution for each sector. In such a way prior information on wind features can be better incorporated in a more familiar way into the adopted prior distributions for the Weibull model parameters. The attained results based on the Mean Square Error show that the rose-plot based on the Bayesian estimates carried out from a 1-month sample is comparable to the actual 1-year one. Such analysis is proposed to cope with actual problems faced by renewable energy companies as encouragingly shown by an application to real anemometric data from a Southern Italian site.

In order to model the directional data collected in a short-term time window (1 month) from the NewStation (located in Southern Italy), the Multinomial distribution is adopted. Prior information has then to be converted into the prior distributions of the 8 Multinomial parameters \( p_j \)’s (which represent the probabilities of each data falling into the \( j \)-th sector).

In the strategy presented, prior information for the NewStation can be deduced from historical data collected at an OldStation in the previous years through the Fisher angular-anchoring association between OlderStation and NewStation [2]. Assuming a multinomial likelihood and a Dirichlet prior \( \Delta(\alpha) \), the posterior distribution \( \Delta(a+s) \) is obtained and can be graphically shown in the following rose-plot (for directions).

In order to furnish the estimates of the wind speed distribution for each sector, the Bayesian approach proposed in [1] is opportunely adjusted. Under the assumption of Weibull distribution of the wind speed, expert information has to be converted into the prior distributions of the Weibull scale and shape parameters.

Markov Chain Monte Carlo (MCMC) technique has been used to obtain the joint posterior distribution of scale and shape parameters of the wind speed distribution. The estimation procedure is numerically implemented by using WinBUGS, an open-source package designed expressly to carry out MCMC computations for a wide variety of Bayesian applicative scenarios. In such a way, the gray rose-plot for directions can be colored in order to summarize also wind speed information.

Results
The Mean Square Error (MSE\(_{\text{Bayes}}\)) of the 1-year rose-plot based on the proposed Bayesian strategy carried out from a 1-month sample is compared with the one (MSE\(_{\text{ML}}\)) based on the classical Maximum Likelihood method and carried out from the same sample. Both rose-plots are compared with the actual 1-year rose-plot obtained at the end of the year (i.e., 11 months later).

Conclusions
• The Bayesian strategy can give a better estimation of wind speed and direction parameters than the Maximum Likelihood one;
• The Bayesian estimates carried out from a short term sample is comparable to the actual values obtained from a one-year sample;
• The short-term Bayesian rose-plot adequately approaches the actual 1-year rose-plot as the monitoring period on NewStation increases.

References

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