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Spatio-Temporal Modeling of Wind Speed Using EOF and Machine Learning

Fabian Guignard[1], Federico Amato[1], Sylvain Robert[2], and Mikhail Kanevski[1]
[1]IDYST, Faculty of Geosciences and Environment, University of Lausanne, Switzerland (fabian.guignard@unil.ch)
[2]Swiss Re, Zurich, Switzerland

Spatio-temporal modelling of wind speed is an important issue in applied research, such as renewable energy and risk assessment. Due to its turbulent nature and its very high variability, wind speed interpolation is a challenging task. Being universal modeling tools, Machine Learning (ML) algorithms are well suited to detect and model non-linear environmental phenomena such as wind.

The present research proposes a novel and general methodology for spatio-temporal interpolation with an application to hourly wind speed in Switzerland. The methodology is organized as follows. First, the dataset is decomposed through Empirical Orthogonal Functions (EOFs) in temporal basis and spatially dependent coefficients. EOFs constitute an orthogonal basis of the spatio-temporal signal from which the original wind field can be reconstructed. Subsequently, in order to be able to reconstruct the signal at spatial locations where measurements are unknown, the spatial coefficients resulted from the decomposition are interpolated. To this aim, several ML algorithms were used and compared, including k-Nearest Neighbors, Random Forest, Support Vector Machine, General Regression Neural Networks and Extreme Learning Machine. Finally, wind field is reconstructed with the help of the interpolated coefficients.

A case study on real data is presented. Data consists of two years of wind speed measurements at hourly frequency collected by Meteoswiss at several hundreds of stations in Switzerland, which has a complex orography. After cleaning and handling of missing values, a careful exploratory data analysis was carried out, followed by the application of the proposed novel methodology. The model is validated on an independent test set of stations. The outcome of the case study is a time series of hourly maps of wind field at 250 meters spatial resolution, which is highly relevant for renewable energy potential assessment.

In conclusion, the study introduced a new way to interpolate irregular spatio-temporal datasets. Further developments of the methodology could deal with the investigation of alternative basis such as Fourier and wavelets.

Reference

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