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Analysis and mapping of monthly wind field patterns using machine learning

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Spatial prediction/mapping of wind speed patterns is important for both renewable resources and natural hazards studies. Many different approaches were proposed in the literature: deterministic science-based models, geostatistical interpolations, data driven modelling based on machine learning algorithms (artificial neural networks of different architectures, support vector machines). Deterministic (science-based or physical) models suffer from computational burden and are hardly applicable over fine grids in complex regions. Geostatistical models depend on modelling of spatial correlations and are limited to the low dimensional spaces.

The present study focuses on the use of machine learning algorithms for spatial mapping of monthly average wind speed in Switzerland. The real data were provided by Meteoswiss and presented complex relationships with topography. The topographic information was derived by filtering the Swiss DEM and was necessary to correctly describe wind speed patterns. Additional input variables, highlighting ridges, canyons, exposed flanks, were stacked to spatial coordinates (X, Y, Z). However, the integration of these "geo-features" considerably increased the dimensionality of the original input space (∼10-30). Therefore the use of machine learning methods became crucial for providing robust nonlinear predictions of high quality.

The generic methodology used includes the following important steps: exploratory spatial data analysis, including variography and detection of spatially structured patterns; automatic features selection/scaling using the adaptive/anisotropic generalized regression neural networks (GRNN); optimization of model hyper-parameters by minimizing cross-validation error using iterative gradient-based algorithms; modelling (mapping) of the functional relationships between the spatial locations and topography, comprehensive analysis of the residuals and visual interpretation of the results.

It was shown that anisotropic GRNN considerably outperforms its isotropic version. Stability of adaptive GRNN in selecting features was assessed by analyzing the variance of the proposed solutions. Other observations concern the variation of the predictability of wind speed during the year: lower in summer and higher in winter. Finally, the results were compared with a support vector regression (SVR), which is a well known non-linear and robust model efficient in high dimensional spaces.

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