
HYPERBOLIC FEATURE ENGINEERING FOR WIND POWER FORECASTING

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ABSTRACT

Wind power forecasting is typically formulated as a supervised learning problem in which prediction models operate on features constructed in Euclidean spaces. However, when wind power time series are represented through probabilistic models, their parameter spaces naturally inherit non-Euclidean geometric structures. In this study, we propose a hyperbolic feature engineering framework grounded in information geometry for wind power forecasting.

The proposed approach begins by representing local segments of wind power time series via parametric modeling using the Weibull distribution, a widely accepted model for wind-related stochastic processes. When endowed with the Fisher information metric, the Weibull family forms a statistical manifold whose parameter space exhibits constant negative curvature under suitable parameterizations. This intrinsic curvature implies that Euclidean embeddings of the parameters distort the geometric relations induced by the underlying statistical model.

Motivated by this observation, we embed the Weibull-derived statistical representations into a hyperbolic space that is consistent with the manifold's negative curvature. Geometry-aware features are then constructed by exploiting the relational structure induced by the hyperbolic metric, rather than relying on handcrafted descriptors or flat vector operations. The resulting features are integrated into standard forecasting models in a model-agnostic manner.

Experimental evaluations demonstrate that aligning feature representations with the information-geometric structure of the Weibull family improves forecasting performance, particularly in capturing nonlinear variability patterns across wind regimes. The proposed framework establishes a principled connection between statistical manifold theory and feature engineering, offering a mathematically consistent pathway for incorporating non-Euclidean geometry into wind power forecasting.

Keywords Statistical Manifolds · Fisher Information Metric · Hyperbolic Feature Engineering

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