

From Fourier to Koopman: Spectral Methods for Long-term Time Series Prediction

Nathan Kutz, University of Washington

We propose spectral methods for long-term forecasting of temporal signals stemming from linear and nonlinear quasi-periodic dynamical systems. For linear signals, we introduce an algorithm with similarities to the Fourier transform but which does not rely on periodicity assumptions allowing for forecasting given potentially arbitrary sampling intervals. We then extend this algorithm to handle nonlinearities by leveraging Koopman theory. The resulting algorithm performs a spectral decomposition in a nonlinear, data-dependent basis. The optimization objective for both algorithms is highly non-convex. However, expressing the objective in the frequency domain allows us to compute global optima of the error surface in a scalable and efficient manner, partially by exploiting the computational properties of the Fast Fourier Transform. Because of its close relation to Bayesian Spectral Analysis, uncertainty quantification metrics are a natural byproduct of the spectral forecasting methods. The efficacy of the algorithms is evaluated on synthetic experiments as well as in the context of predicting signals in the realms of power systems and fluid flows.