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Reduced nonlinear prognostic model construction from high-dimensional data

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Construction of a data-driven model of evolution operator using universal approximating functions can only be statistically justified when the dimension of its phase space is small enough, especially in the case of short time series. At the same time in many applications real-measured data is high-dimensional, e.g. it is space-distributed and multivariate in climate science. Therefore it is necessary to use efficient dimensionality reduction methods which are also able to capture key dynamical properties of the system from observed data.
To address this problem we present a Bayesian approach to an evolution operator construction which incorporates two key reduction steps. First, the data is decomposed into a set of certain empirical modes, such as standard empirical orthogonal functions or recently suggested nonlinear dynamical modes (NDMs) [1], and the reduced space of corresponding principal components (PCs) is obtained. Then, the model of evolution operator for PCs is constructed which maps a number of states in the past to the current state. The second step is to reduce this time-extended space in the past using appropriate decomposition methods. Such a reduction allows us to capture only the most significant spatio-temporal couplings.
The functional form of the evolution operator includes separately linear, nonlinear (based on artificial neural networks) and stochastic terms. Explicit separation of the linear term from the nonlinear one allows us to more easily interpret degree of nonlinearity as well as to deal better with smooth PCs which can naturally occur in the decompositions like NDM, as they provide a time scale separation.
Results of application of the proposed method to climate data are demonstrated and discussed.
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1. Mukhin, D., Gavrilov, A., Feigin, A., Loskutov, E., & Kurths, J. (2015). Principal nonlinear dynamical modes of climate variability. Scientific Reports, 5, 15510. http://doi.org/10.1038/srep15510