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Data-based Non-Markovian Model Inference

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This talk concentrates on obtaining stable and efficient data-based models for simulation and prediction in the geosciences and life sciences. The proposed model derivation relies on using a multivariate time series of partial observations from a large-dimensional system, and the resulting low-order models are compared with the optimal closures predicted by the non-Markovian Mori-Zwanzig formalism of statistical physics.

Multilayer stochastic models (MSMs) are introduced as both a very broad generalization and a time-continuous limit of existing multilevel, regression-based approaches to data-based closure, in particular of empirical model reduction (EMR). We show that the multilayer structure of MSMs can provide a natural Markov approximation to the generalized Langevin equation (GLE) of the Mori-Zwanzig formalism.

A simple correlation-based stopping criterion for an EMR-MSM model is derived to assess how well it approximates the GLE solution. Sufficient conditions are given for the nonlinear cross-interactions between the constitutive layers of a given MSM to guarantee the existence of a global random attractor. This existence ensures that no blow-up can occur for a very broad class of MSM applications.

The EMR-MSM methodology is first applied to a conceptual, nonlinear, stochastic climate model of coupled slow and fast variables, in which only slow variables are observed. The resulting reduced model with energy-conserving nonlinearities captures the main statistical features of the slow variables, even when there is no formal scale separation and the fast variables are quite energetic.

Second, an MSM is shown to successfully reproduce the statistics of a partially observed, generalized Lokta-Volterra model of population dynamics in its chaotic regime. The positivity constraint on the solutions' components replaces here the quadratic-energy–preserving constraint of fluid-flow problems and it successfully prevents blow-up.

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