BAYESIAN IDENTIFICATION OF NONSEPARABLE HAMILTONIAN SYSTEMS USING STOCHASTIC DYNAMIC MODELS

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ABSTRACT

Nonseparable Hamiltonian systems arise as models in many science and engineering applications such as multibody dynamics and control in robotics, the Kozai-Lidov mechanism in astrophysics, particle accelerators in accelerator physics, and the nonlinear Schrödinger equation in quantum mechanics. These systems demonstrate complex nonlinear behavior while possessing an underlying highly structured geometry encoded by a Hamiltonian. Learning Hamiltonian models directly from data is becoming increasingly important in diverse areas such as astrophysics, robotics, fluid dynamics, plasma physics, and quantum mechanics where first-principle modeling can yield highly complex model structures or such models are not available. We propose a probabilistic Bayesian formulation for system identification and estimation of nonseparable Hamiltonian systems using stochastic dynamic models. Our approach embeds the physics underlying nonseparable Hamiltonian structure into the learning formulation to develop a probabilistic learning method that preserves the symplectic structure intrinsic to Hamiltonian dynamics. The numerical experiments with the proposed method demonstrate that the new method recovers dynamical systems with higher accuracy and reduced predictive uncertainty compared to state-of-the-art approaches. The results further show that accurate predictions far outside the training time interval in the presence of sparse data and noisy measurements are possible, which lends robustness and generalizability to the proposed approach.