Structure-preserving model order reduction of parametric Hamiltonian systems

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Model order reduction of parametric differential equations aims at constructing low-complexity high-fidelity surrogate models that allow rapid and accurate solutions under parameter variation. The development of reduced order models for Hamiltonian systems is challenged by several factors: (i) failing to preserve the geometric structure encoding the physical properties of the dynamics might lead to instabilities and unphysical behaviors of the resulting approximate solutions; (ii) the slowly decaying Kolmogorov n-width of transport-dominated and non-dissipative phenomena demands large reduced spaces to achieve sufficiently accurate approximations; and (iii) nonlinear operators require hyper-reduction techniques that preserve the gradient structure of the flow velocity. We will discuss how to address these aspects via a structure-preserving nonlinear reduced basis approach based on dynamical low-rank approximation. The gist of the proposed method is to adapt in time an approximate low-dimensional phase space endowed with the geometric structure of the full model and to ensure that the reduced flow is still Hamiltonian.