Structure-Preserving Model Order Reduction (SP-MOR)

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In order to be reliable predictive tools, reduced order models (ROMs) must preserve the key properties of the underlying partial differential equations from which they are constructed. It is well known that ROMs in general do *not* automatically inherit the properties of their corresponding full order models (FOMs). This poster describes several new property-preserving model order reduction (MOR) methods currently being developed under the M2dt MMICC-3 project: (1) energy-stable operator inference (OpInf), (2) Hamiltonian SP-MOR, and (3) Hodge de Rham (HdR) complex-preserving SP-MOR. The first two properties are considered geometric properties, whereas the third is a topological property.

The first approach, energy-stable OpInf, exploits the inherent embedded symmetries present in parameterized dynamical systems obeying an energetic stability property. The operators defining this SP-ROM are learned in a non-intrusive fashion by solving an offline optimization problem using available FOM snapshot data. The second approach highlighted is a novel non-intrusive OpInf technique guaranteed to preserve the structure of canonical and non-canonical Hamiltonian systems. The method reduces to a straightforward linear solve given snapshot data and "gray-box" knowledge of the underlying problem. The last approach aims to develop ROMs which preserve the HdR decomposition of a given differential form, required for any mimetic discretization. We present a recently-formulated projection-based SP-MOR technique in which the de Rham commutative diagram is preserved in the ROM projection step through a clever choice of test and trial bases.

We demonstrate that, unlike traditional MOR methods, the proposed approaches deliver stable, accurate, energy-conserving and robust ROMs.