Structure-preserving methods for simulation and learning of dynamical systems

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The classical approach to predicting behavior of dynamical systems is to treat the mathematical modeling and the numerical integration as subsequent steps. Contrarily, structure-preserving methods, as they have been developed particularly for mechanical systems, intertwine them to generate discrete-time models, still based on first-principle modeling. Motivated by the growing interest in machine learning, we revisit these methods to study the potential of data-based enhancements.
This presentation gives insight into three aspects of this endeavor: Firstly, Hamiltonian neural networks which preserve and learn unknown system invariances, namely affine-linear Lie group symmetries, are introduced for system identification. Secondly, we present AI-enhanced symplectic numerical integrators which allow a structure-preserving efficiency increase. Lastly, we consider dynamical control systems possessing symmetry-induced relative equilibria, known as motion primitives. These primitives can be extracted from data as we demonstrate in an autonomous driving application.

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