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SympFlow: Neural Symplectic Flows for dissipative systems and its application to GW modelling.

Hamiltonian and Lagrangian equations of motion are the workhorse of Theoretical Physics. The behaviour of physical systems is analytically described by a set of, usually complex, PDEs and ODEs. Consequently, the time evolution of such systems requires numerical integrators and in the case of, e.g., black hole binary evolution, this is, in most cases, computationally expensive or even prohibitive due to the different temporal and spatial scales involved. Different waveform approximants have been developed to model different binary evolution stages, like the inspiral, merger, and ring-down phases. However, these waveform approximants do not cover the full parameter space of interest and "stitching" together the different models consistently is still an open problem.

To address this problem, we present SympFlow, a novel neural network-based Symplectic integrator that can account for dissipation, that is, nonconservative interactions. Our approach extends neural networks to model the evolution of equations of motion and includes dissipative effects in PINN-like integrators.

The key benefits of SympFlow include:
(1) it is mesh-free,
(2) it does not require training data, and
(3) it can be used for different initial conditions, generating a solution bundle suitable for Bayesian inference.

We demonstrate the applicability of SympFlow to evolve conservative and dissipative systems, comparing its performance against classical integration methods on several test problems.

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