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Structure-Preserving Neural Networks for the N-body Problem

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In order to understand when it is useful to add physics constraints into neural networks, we investigate different neural network topologies to solve the N-body problem. Solving the chaotic N-body problem with high accuracy is a challenging task, requiring special numerical integrators that are able to approximate the trajectories with extreme precision. In [1] it was shown that a neural network can be a viable alternative offering solutions many orders of magnitudes faster. Specialized neural network topologies for applications in scientific computing are still rare compared to more classical machine learning applications. However, the number of specialized neural networks for Hamiltonian systems has been growing during the last years [2, 3]. We analyze the performance of SympNets introduced in [3], preserving the symplectic structure of the phase space flow map, for the prediction of trajectories in N-body systems. In particular we compare the long-term stability of predictions of stable two-body orbits by SympNets, against predictions by standard multilayer perceptrons. While the benefits of symplectic integrators for Hamiltonian systems are well understood, this is not the case for SympNets. Possible benefits include: better extrapolation outside of the training data, more regularized predictions also inside the range of training data and improved optimization behavior due to the reduced search space.

REFERENCES

[1] P.G. Breen, C.N. Foley, T. Boekholt and S. Portegies Zwart, Newton versus the machine: solving the chaotic three-body problem using deep neural networks, *Monthly Notices of the Royal Astronomical Society*, Vol. **494**, pp. 2465-2470, 2020.

[2] S. Greydanus, M. Dzamba and J. Yosinski, Hamiltonian neural networks, *Advances in Neural Information Processing Systems*, Vol. **32**, NeurIPS, 2019.

[3] P. Jin, Z. Zhang, A. Zhu, Y. Tang and G.E. Karniadakis, SympNets: Intrinsic structure-preserving symplectic networks for identifying Hamiltonian systems, *Neural Networks*, Vol. **132**, pp. 166-179, 2020.