The First CSU Mathematical Conference

California State University, Northridge

November 11–12, 2022, Northridge, California

Hamiltonian Neural Network Exploration for Electron Particle Tracking

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Key Words: Hamiltonian Mechanics, neural network, machine learning, python, particle accelerator, light sources, particle tracking

In the field of accelerator physics, there is a burgeoning interest in using machine learning methods for aiding in the design and optimization of charged particle accelerators. The Advance Light Sources (ALS) at the Lawrence Berkeley National Laboratory is a periodic circular accelerator called a synchrotron that emits ultraviolet and soft x-ray beams by accelerating electron bunches nearly as fast as the speed of light. These accelerators are prone to beam instability resulting in particle loss and consequently creating less x-ray brightness. The stability of an electron over thousands of revolutions is important to the performance of the accelerator. During these machines’ design or upgrade process, electron particle tracking is needed to ensure the particle dynamics are sufficient for the intended scientific use, but can be computationally expensive. If the dynamic aperture, the stability region of phase space in the synchrotron, is too small, then adjustments are made and the process is repeated until the desired result is achieved. Optimizing the dynamic aperture can require doing this tracking several times while iterating the accelerator design. Machine learning methods may alleviate some of the need for these expensive computations by making particle integration faster and easier to parallelize. This research explores electron particle tracking with the use of Hamiltonian Neural Networks. Machine learning based Hamiltonian Neural Networks (HNN) constrains the model learning to obey Hamiltonian mechanics so that the neural network can learn conservation laws from data [3]. We compare the performance of HNN to other machine learning based models [2].

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