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Accelerating kinetic simulations of magnetic-confinement fusion devices utilizing encoder-decoder neural networks to numerically solve the nonlinear Fokker-Planck collision operator

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Collisional transport is a critical physical process in the edge of fusion tokamak plasmas, yet for kinetic simulations with multiple ion species numerically solving for collisional transport becomes prohibitively expensive. We present here a machine learning method, based on an encoder-decoder neural network, which numerically solves a multi-species, fully nonlinear Fokker-Planck (FP) collision operator. This neural network is trained on particle distribution function data generated from the XGC code, which is a massively parallel, gyrokinetic turbulence code focused on simulating the edge of tokamak plasmas. The neural network is trained using a novel stochastic Augmented Lagrangian method, such that its objective includes not only matching the output distribution function from the collision operator, but also a penalty for solutions which do not respect the known particle, momentum, and energy conservation properties of the FP operator. Current status will be discussed, focusing on the integration of this neural network into the XGC code, including long-time behavior of the neural network based solution.

References:

Miller, M.; et. al. "Encoder-decoder neural network for solving the nonlinear Fokker-Planck-Landau collision operator in XGC", https://arxiv.org/abs/2009.06534
Dener, A; et. al. "Training neural networks under physical constraints using a stochastic augmented Lagrangian approach" https://arxiv.org/abs/2009.07330