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Classification of accelerated particles in plasma simulations using neural networks

Cosmic ray (CR) acceleration processes can be studied by using a fully-kinetic treatment for plasma simulations, e.g., particle-in-cell (PIC) simulations, that allow us to describe a detailed microphysics responsible for CR acceleration. Particle tracing implemented in many PIC codes is able to store full datasets for selected high-energy particles. However, the by-eye inspection of particle trajectories includes a high level of bias and uncertainty, and pinpointing the specific acceleration mechanisms is very difficult. Therefore, we propose a method to predict the energy of particles by using supervised Neural Networks (NN). The dataset used is taken from our recent PIC simulations of nonrelativistic perpendicular shocks and consists of approximately 40000 particles with 4 different variables, each associated with a time series of 1200 time steps long. These particles cross a region affected by the Buneman instability, upon which a few percentages of them reach high energies. We perform classification and regression on the dataset by using a Convolutional NN and a Multi-Layer Perceptron. Both methods are able to predict real particle energies with high precision, despite the noisy and imbalanced dataset. Proposed methodology may considerably simplify particle classification in large-scale PIC and hybrid simulations.

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