Convolutional neural network models for predicting evolution of nonlinear gyrokinetic simulations

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Nonlinear gyrokinetic simulations are performed to calculate fluxes caused by turbulent fluctuations, which dominate the confinement performance of fusion plasmas. In such simulations, the time evolution of the perturbed distribution function is solved in the five-dimensional phase space, and it takes a few days or more on supercomputers. We have developed convolutional neural network (CNN) models to support efficient runs of gyrokinetic codes.

Our first CNN model reads the images, which are generated at a time interval throughout the simulations and show the perturbed distribution function in the two-dimensional wavenumber-space [1]. Here, the calculations are performed with the gyrokinetic code GKV [2]. The CNN model has been built by employing transfer learning and fine-tuning techniques based on the EfficientNet-B4 [3], which is pre-trained on a large number of real-world images, and it predicts the simulation time at which the image was processed. The simulation time predicted by the CNN model can be utilized to optimize the initial condition for lower computational resources.

We next extended the capability of the model to predict the fluxes quantitatively [4]. Our second model is a multimodal CNN model, which reads the magnitude of the electrostatic potential as a value as well as the images and forecasts the simulation time and the electron and ion heat fluxes. The multimodal CNN model was trained on data produced by the simulation for the Cyclone base case (CBC), which is a de facto standard DIII-D parameter set for the gyrokinetic simulation benchmarking test. When the CBC-based predictor is applied to the simulation for a JT-60U plasma parameter set, it successfully forecasts the heat fluxes [4]. Such high predictability can be attributed to the fact that turbulence of both the CBC and the JT-60U case is dominantly driven by the same instability. If a test case has other dominant instability, a predictor trained on the equivalent case can be applied.

References

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