PiAI Seminar Series: Physics informed AI in Plasma Science
9:30-10:30, 16 November 2020 (CET)
17:30-18:30, 16 November 2020 (JST)
Web Seminar

Neural-network assisted transport simulations of fusion plasmas

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Since fusion power is severely affected by plasma density and temperature, predicting them is a crucial issue in fusion research. Integrated transport codes are usually used to this end, and a turbulent transport model implemented in the codes largely determines the prediction quality, especially for tokamak plasmas. Therefore, the turbulent transport model is required to describe underlying turbulence physics in detail, but introducing the detailed descriptions leads to an increase in the computational cost. Using reduced turbulent transport models founded on first-principle-based gyrokinetic simulations shows reasonable agreement with experimental observations, but it takes from several hours to days to obtain a steady-state density and temperature profile with parallel computation. To accelerate integrated transport simulations, a neural-network (NN) based approach has been undertaken, and NN models successfully predict transport fluxes from 10^3 to 10^5 times faster than the reduced transport models. Most NN models mimic the performance of the reduced turbulent transport models [1-3] while our model, DeKANIS, has been trained with gyrokinetic calculation results and experimental data [4]. DeKANIS has also the feature that it distinguishes diffusion and convective transport processes. Outputs from DeKANIS are categorized into two groups: one is the coefficients that determine the ratio of the transport quantity driven by each process to the whole transport flux, and the other assesses the magnitude of the transport flux. The training data for the former is given by the gyrokinetic calculations, and that for the latter is based on the JT-60U experimental data. DeKANIS calculates the outputs with a fully-connected feed-forward NN model that expresses the relationship between the outputs and the plasma parameters characterizing turbulent transport. The hyperparameters and activation functions of the NN model have been optimized for integrated transport simulations. DeKANIS realizes accurate predictions of the density and temperature profiles within a few hours, and it will also be utilized to understand the effects of the transport processes on profile formation by making use of its feature.

[1] J. Citrin *et al*., Nucl. Fusion **55** 092001 (2015).
[2] O. Meneghini *et al*., Nucl. Fusion **57** 086034 (2017).
[3] M. Honda and E. Narita, Phys. Plasmas **26**, 102307 (2019).
[4] E. Narita *et al*., Nucl. Fusion **59** 106018 (2019).