Deep Learning for the modeling of electron nonlocal transport in plasmas

C. Lamy[1], B. Dubroca[2], Ph. Nicolaï[1], V. Tikhonchuk[1 3], J.-L. Feugeas[1]

[1] *University of Bordeaux-CNRS-CEA, Centre Lasers Intenses et Applications, UMR 5107, 33405 Talence, France*

[2] *University of Bordeaux-CNRS-CEA-SAFRAN, Laboratoire des Composites Thermostructuraux, UMR 5801, 33600 Pessac, France*

[3] *ELI-Beamlines Center, Institute of Physics, CAS, 25241, Dolní Břežany, Czech Republic*

Nowadays, the modeling of non-local electronic transport remains an important issue for the simulation of plasma physics experiments, such as inertial confinement fusion (ICF). Kinetic models are the reference tools for calculating nonlocal fluxes, but their calculation time is not compatible with hydrodynamic simulations. Approximate macroscopic models have been developed to overcome this problem, and some of them are now implemented in hydrodynamic computation codes. However, their use in 2D and 3D simulations remains a numerical challenge. Moreover, the addition of effects, such as magnetic fields, makes their use even more difficult and further increases the calculation time.

Artificial Neural Networks are used in a large number of diverse and varied applications[1], including in numerical simulation. In the latter, neural networks are generally coupled with classical simulation codes which solve partial differential equations using numerical schemes. A neural network is then a means of replacing part of the calculation code, in order to improve its performance in terms of execution time, while maintaining good precision.

This study proposes to replace a modeling module of the non-local heat transport of electrons by an artificial neural network inside a hydrodynamic simulation. The module uses the Schurtz-Nicolaï-Busquet nonlocal flux model[2], and is part of the hydrodynamic code CHIC[3], which is used for the simulation of inertial confinement fusion experiments. The first results of the coupling of a neural network with CHIC have excellent precision (3% maximum error within a radius of 0.5 μm) while having a reduced calculation time (gain of a factor of 433 in 2D)[4].

References

[1] I. Goodfellow, Y. Bengio and A. Courville, *Deep Learning*, MIT Press (2016).

[2] Schurtz, G. P. and Nicolaï, Ph. D. and Busquet, M., *A nonlocal electron conduction model for multidimensional radiation hydrodynamics codes*, Phys. Plasmas, **7**, 4238 (2000).

[3] Breil, J. and Galera, S. and Maire, P.-H., *Multi-material ALE computation in inertial confinement fusion code CHIC*, Computers & Fluids, **46**, 161 (2011).

[4] Lamy, C. and Durboca, B. and Nicolaï, Ph. and Tikhonchuk, V. and Feugeas J.-L., *Modeling of electron nonlocal transport in plasmas using artificial neural networks*, Physical Review E, **105**, 055201 (2022).