Surrogate modelling using feed forward neural networks for turbulent transport in fusion plasmas

[1*]van de Plassche, K.L., [1]Citrin, J., [2]Bourdelle, C., [3]Camenen, Y., [4]Casson, F.J., [1]Dagnelie, V.I., [5]Felici, F., [1]Ho, A & [†]JET Contributors

∗ lead presenter

[1]*DIFFER, PO Box 6336, 5600 HH Eindhoven, The Netherlands*

[2]*CEA, IRFM, F-13108 Saint-Paul-lez-Durance, France*

[3]*CNRS, Aix-Marseille Univ., PIIM UMR7345, Marseille, France*

[4]*CCFE, Culham Science Centre, Abingdon, UK*

[5]*EPFL-SPC, CH-1015, Lausanne, Switzerland*

[†]*See the author list of* X. Litaudon et al 2017 Nucl. Fusion 57 102001

∗ k.l.vandeplassche@differ.nl

Surrogate models approximate more complex, computationally expensive models while being faster to run. They can be used for tasks where using the slow original model is infeasible, for example in optimization and control. In this work we apply this methodology within a fusion energy context, using feed-forward neural networks (FFNNs) as a surrogate model five orders of magnitude faster than the underlying model: the quasilinear turbulent transport code QuaLiKiz[1, 2]. QuaLiKiz is used to describe heat, particle, and momentum transport in tokamaks, and was used to create a large database of 3.10^8 flux calculations using 1.3 MCPUh on HPC resources (Edison@NERSC). Embedding known physical constraints in the training of the networks is essential for the surrogate model to perform well in transport predictions. As such, we show the importance of choosing the right cost function and more fundamentally, choosing which target variables the networks have to be trained on. Custom figures of merit and visualisation tools were developed to aid with neural network accuracy verification.

The neural network surrogate turbulent transport model is applied within the RApid Plasma Transport Simulator RAPTOR[3, 4] and the integrated modelling suite JINTRAC [5] to predict the temperature and density evolution of JET fusion plasmas, in excellent agreement with the original QuaLiKiz model, yet orders of magnitude faster. This allows us to simulate one second of plasma evolution in 10 seconds, a speed that is unprecedented for first-principle based transport simulations, opening up new avenues for tokamak scenario optimization and realtime control applications.

References

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