Real time capable turbulent transport modelling using neural networks

K. van de Plassche[1], J. Citrin[1], C. Bourdelle[2], V. Dagnelie[1,3], F. Felici[4], A. Ho[1]

[1] *DIFFER - Dutch Institute for Fundamental Energy Research, Eindhoven, the Netherlands*

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

[3] *Utrecht University, Princetonplein 5, 3584 CC, Utrecht, The Netherlands.*

[4] *EPFL-SPC, CH-1015, Lausanne, Switzerland.*

Quasilinear gyrokinetic models are very successful in predicting particle and heat transport in tokamaks, and in reproducing experimental profiles in wide parameter regimes. One such code is QuaLiKiz, validated on JET, ASDEX-U and Tore-Supra discharges [1, 2, 3, 4]. While an impressive six orders of magnitude faster than local nonlinear gyrokinetics, they are still too slow for efficient scenario optimization and realtime applications.

A feed-forward neural network regression of QuaLiKiz was used in a successful proof-of-concept [5, 6]. Such a network can be evaluated within a few microseconds, another six orders of magnitude faster than the original model. These networks are tested and designed for the RAPTOR rapid profile evolution code [7], but can also be used in other frameworks.

This current work is a major extension of the proof-of-principle from 4D to 10D. A large database of 3.10^8 flux calculations over a 9D input space generated with the QuaLiKiz code is used to extend the original input space of ion temperature gradient R/L_{T_i}, ion-electron temperature ratio T_i/T_e, safety factor q and magnetic shear $\hat{s}$ with the electron temperature gradient R/L_{T_e}, density gradient R/L_n, minor radius ρ, collisionality ν^* and effective ion charge Z_{eff}. The 10^{th} dimension, ExB shear, is added in post-processing using a new turbulence quenching rule [8].

We present our methodology of training and validating these neural networks, which are ready for applications within RAPTOR [9]. The speed of the networks created in this work combined with RAPTOR allow for transport simulations at a speed that is unprecedented, and opens new avenues in the modelling of fusion experiments.

References

[1] J. Citrin *et al.* Plasma Physics and Controlled Fusion **59** 12400 (2017)
[2] C. Bourdelle *et al.*, Plasma Physics and Controlled Fusion **58**, 1 (2016)
[3] O. Linder *et al.*, to be submitted to Nuclear Fusion
[4] M. Marin *et al.*, this conference (EPS Prague 2018); A. Ho *et al.*, this conference (EPS Prague 2018)
[5] J. Citrin *et al.* Nuclear Fusion **55** 092001 (2015)
[6] F. Felici *et al.*, submitted to Nuclear Fusion
[7] F. Felici and O. Sauter, Plasma Physics and Controlled Fusion **54**, 2 (2012)
[8] V.I. Dagnelie *et al.* University of Utrecht MSc thesis (2017)
[9] F. Felici *et al.*, this conference (EPS Prague 2018)