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P1.1089 Near-realtime tokamak scenario simulation with neural networks

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Accurate prediction of turbulent transport is essential for interpretation of current-day fusion experiments, designing future devices, and optimization of plasma scenarios. Turbulent transport in the core of the plasma is well-described by quasilinear theory, which can be leveraged to create reduced models. These are then applied within flux driven integrated modelling to predict time evolution of temperature, density, and rotation profiles in fusion devices. Recent developments in the QuaLiKiz gyrokinetic quasilinear transport model [1, 2] within the JINTRAC integrated modelling suite [3] has provided validated prediction of JET and AUG scenarios, with 1s of plasma evolution predicted in 24 hours using 10 cores [4, 5].
We provide further significant speedup of first-principle-based turbulent transport modelling sufficient for large scale reactor optimization and control oriented applications. We apply feedforward neural networks (FFNNs) for regression of a pre-generated QuaLiKiz database consisting of 108 flux calculations. The resultant neural network surrogate model is 5 orders of magnitude faster than QuaLiKiz itself. Generic neural network training is not sufficient to correctly capture known physical features of tokamak turbulence, such as sharp instability thresholds common to all transport channels. We show how we can incorporate these features directly in the training process.
The surrogate turbulent transport model is applied within the rapid plasma transport simulator RAPTOR [6, 7] and JINTRAC. We show that the predictions of temperature and density evolution of JET plasmas are in excellent agreement with the original QuaLiKiz model, yet orders of magnitude faster. This allows us to simulate one second of plasma evolution in less than 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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