First-principle-based and tractable flux-driven turbulent tokamak transport modelling

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An accurate and predictive model for turbulent transport is a vital component of predictive tokamak plasma simulation. For scenario optimisation and control-oriented applications, realtime capable modelling is required. However, while direct numerical nonlinear simulations provide turbulence predictions in agreement with experiment, the computation times involved are orders of magnitude too slow. We sketch a path towards circumventing the conflicting constraints of accuracy and tractability. First, reduced turbulence models [1,2], justified through the quasilinear approximation and validated by comparison to experiments, leads to a significant computational speedup of 6 orders of magnitude compared to nonlinear models. A faster reduced model then facilitates a machine learning approach; extensive datasets of reduced turbulence model calculations are created, deploying HPC-scale resources. These datasets form training sets for feed forward neural networks to reproduce the original model predictions. This approach provides a further 6 orders of magnitude speedup, 1 trillion times faster than nonlinear simulations [3,4]. The datasets are created either by direct grid scans in tokamak parameter space [5], or by constraining the subspace to experimental discharge parameters through extensive selection and processing of experimental databases, facilitated by Gaussian Process Regression techniques [6]. By coupling the neural network transport models to control-oriented fast tokamak simulator such as RAPTOR [7], realtime-capable transport predictions are now possible. This opens up a plethora of possibilities and innovation in realtime controller design and validation, scenario preparation, and discharge optimization.

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