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Neural network surrogate modelling of tokamak plasma turbulence

JONATHAN CITRIN, DIFFER, Eindhoven, The Netherlands, CLARISSE BOURDELLE, CEA, IRFM, Saint Paul Lez Durance, France, YANN CAMENEN, CNRS, Aix-Marseille Univ., Marseille, France, FEDERICO FELICI, SPC/EPFL, Lausanne, Switzerland, AARON HO, PHILIPP HORN, BART KREMERS, KAREL VAN DE PLASSCHE, DIFFER, Eindhoven, The Netherlands

Tokamak plasma confinement is constrained by turbulence. Reactor optimization demands accurate and tractable turbulence calculations, infeasible with high-fidelity DNS. Neural Network (NN) surrogate models circumvent the conflicting constraints of accuracy and tractability. A key enabling step is the development of reduced order models, validated by nonlinear simulations. Reduced model calculation time is sufficient for constructing extensive databases of model input-output mappings using HPC resources. These are used as training sets for NN regression. A key aspect is the physics-informed customization of regression variables and optimization cost functions, to capture known features of the system. The resultant NN transport models accurately reproduce the original reduced turbulence model with significant speedup, providing near-realtime capability, 1 trillion times faster than the anchoring nonlinear simulations. We summarize the state-of-the-art in tokamak transport NN surrogate development based on the QuaLiKiz model, ranging from grid-based input-space approaches, sampling input space based on pre-selected experimental databases including clustering and data-reduction approaches, and modification of the NN topologies to better capture the structure of the input-output mapping.