Accelerated predictive models for scenario optimization and control of tokamaks

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Model-based control and scenario development for fusion devices rely on a hierarchy of models of varying fidelity and speed. Integrated modeling codes, like TRANSP, can provide high-fidelity simulation capability, but are incompatible with real-time implementation. Data-driven reduced modeling based on higher fidelity models provides a path for developing accelerated predictive models for these tasks. Several such models have been developed for NSTX-U including a real-time capable neural network beam model, NubeamNet, that calculates heating, torque, and current drive profiles from equilibrium parameters and measured profiles. Models have also been developed for real-time evaluation of plasma conductivity, bootstrap current, and flux surface averaged geometric quantities for use in current profile control and estimation algorithms. Model uncertainty is addressed through an ensemble modeling approach, which is shown to provide an indication of the valid input space of the resulting models. Approaches to hyperparameter tuning have been studied to enable optimization of generalization and complexity and hardware-in-the-loop simulations in the NSTX-U plasma control system show suitability of the models for real-time applications. Initial applications, including estimation of anomalous fast ion diffusivity to match measured neutron rates, will be presented.