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EFIT-AI neural network surrogates for magnetic, MSE, and kinetic equilibrium reconstruction

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Artificial neural network (NN) surrogate models have been developed and trained on magnetic, magnetic + motional stark effect (MSE), and kinetic DIIII-D equilibria to accelerate tokamak equilibrium reconstructions for offline, between-shot, and real-time applications. Adaptation of the ML/AI algorithms has been facilitated through the recently developed device-independent portable equilibrium solver and a large EFIT database of DIII-D magnetic, MSE and kinetic equilibria[1]. The main model comprises a fully connected NN coupled to a convolutional NN that together enforce the toroidal force-balance constraint by concurrently learning the poloidal flux and toroidal current density on the EFIT spatial grid. In addition, the NN surrogates also predict pressure, current, P', FF', and safety factor (q) profiles, and important plasma parameters such as the internal inductance, normalized beta, and magnetic axis location. Models are optimized for both architecture and hyperparameters, as well as inference speed, which has been clocked at real-time EFIT-like speeds.

The NN surrogates for the magnetic EFITs show generalizability to previously-unseen negative-triangularity shapes, by incorporating the spatial correlation among various magnetic sensors in DIII-D into the NN input vector. The magnetic + MSE surrogates show improved predictions of the q profiles, and certain plasma parameters like the internal inductance. Finally, the kinetic surrogates show additional improvements in accurately reproducing EFIT-predicted internal current and pressure profiles. These results suggest the possibility of using a surrogate model as a real-time tool for plasma control and other applications.

[1]. L. Lao et al., PPCF, 64, 074001 (2022)

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