Real-time capable neural network approximation of NUBEAM for use in the NSTX-U control system

M.D. Boyer[1], S. Kaye[1], D. Liu[2], K. Erickson[1], W. Heidbrink[2],

O. Meneghini[3], S.A. Sabbagh[4]

[1] *Princeton Plasma Physics Laboratory, Princeton, NJ, USA*

[2] *University of California-Irvine, Irvine, CA, USA*

[3] *General Atomics, San Diego, CA, USA*

[4] *Columbia University, New York, NY, USA*

Present-day and next step tokamaks will require precise control of plasma conditions, including the spatial distribution of rotation and current profiles, in order to optimize performance and avoid physics and operational constraints. The coupled nonlinear dynamics of equilibrium profiles and the complex effects of actuators on the equilibrium evolution motivates embedding physics-based models within real-time control algorithm designs. Due to the important role of beam heating, current drive, and torque in establishing scenario performance and stability, a high-fidelity beam model suitable for use in real-time applications is desired. This work describes a neural network that has been developed to enable rapid evaluation of the beam heating, torque, and current drive profiles based on measured equilibrium profiles. The training and testing database has been generated from the NUBEAM calculations output from interpretive TRANSP analysis of shots from the 2016 NSTX-U campaign, including scans of Zeff and fast ion diffusivity. Neural network predictions made for the testing data demonstrate the ability of the model to generalize and accurately reproduce NUBEAM calculated profiles and scalar quantities. Results of hardware-in-the-loop simulations of the model within the NSTX-U plasma control system will be presented, along with plans and progress toward application of the neural network for accelerated offline analysis and real-time control.

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