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From data-based accelerated neural network model to physics-based neural network without human knowledge: focused on plasma equilibrium reconstruction

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We present a neural network (NN) based magnetic-equilibrium-reconstruction model without sacrificing both reconstruction quality and real-time application [1].

The database collected to train the network's free parameters includes off-line EFIT (a widely used equilibrium fitting code by solving Grad-Shafranov equation numerically) results from 1,118 KSTAR discharges of two different campaigns with spatial positions and magnetic data including plasma current measured by a Rogowski coil and magnetic fields measured by magnetic pick-up coils.

With Tensorflow based supervised learning, the NN reproduces off-line-EFIT quality equilibria in real time, receiving not only the magnetic signals but also the spatial R, Z information as its inputs. As a spatial information is an input parameter, the network is able to generate a higher spatial resolution of the equilibria compared to the original EFIT results and compute any arbitrary position. The network generality is proven with unseen experimental KSTAR EFIT data using three different figure of merits which are a mean structural similarity, a peak signal-to-noise ratio and a mean squared error. To make the network robust against possible loss of input signals such as magnetic signals, we use an imputation scheme [2] developed based on Bayesian inference and Gaussian processes.

Furthermore, going one step forward, we expect that a network is able to learn, *tabula rasa*, equilibrium reconstructions by solving Grad-Shafranov equation directly based on unsupervised learning without requiring any experimental data or simulation codes such as EFIT.

References

[1] S. Joung et al., Nucl. Fusion 60, 0160334 (2020)
[2] S. Joung et al., Rev. Sci. Instrum. 89, 10K106 (2018)