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Reconstruction of plasma equilibrium using physics-informed neural network on EAST

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The traditional algorithm currently used for plasma equilibrium reconstruction in tokamaks assumes a plasma current profile in a certain polynomial form (usually 2nd or 3rd order) or a tension spline function and performs a least square fitting to the diagnostic data under the model given by the Grad-Shafranov equation 1. The physics-informed neural network (PINN) integrates measurement data and mathematical models governed by parameterized PDEs and implements them through neural networks, so the networks can be trained from additional information obtained by enforcing the physical laws 2. The inverse problems solving with PINN on JET demonstrates its great potential for plasma equilibrium reconstruction with external magnetic diagnostics in tokamak [3].

Instead of using meshless method, a new physics-informed neural network with fixed fine grids was developed to reconstruct EAST plasma shape based on external magnetic diagnostics. The basic neural network architecture is composed of two separate hidden layer sections. The first section, consisted of 6 hidden layers with 20 neurons each, aims to predict the poloidal flux based on the given points on the specified grids as input. The second section has 2 hidden layers with 10 neurons each, which was designed to calculate plasma pressure and poloidal current flux from the poloidal flux. The selected loss function includes 5 parts: the predicted poloidal flux of flux loops and the predicted poloidal magnetic field of pick-up coils against the measured one, the residuals for Grad-Shafranov equation of grids inside and outside the plasma separatrix, the plasma pressure and poloidal current flux of points on plasma separatrix, the total plasma current difference between the predicted and the measured one, and the poloidal flux of flux loops and poloidal magnetic field of pick-up coils calculated by Green's function of fixed grids and external magnetic diagnostics against the measured one. The calculation results using this new physics-informed neural network verify the effectiveness to reconstruct EAST plasma shape based on simulated equilibrium dataset w/wo random noises. Reconstructed results with magnetic diagnostics from EAST discharge confirm the reliability. The new PINN approach can provide another viable method to reconstruct the plasma shape for EAST tokamak.

References

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