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再帰型ニューラルネットワークを利用したプラズマ垂直位置の予測

Prediction of Plasma Vertical displacement by Using LSTM Recurrent Neural Network

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Since plasmas with a D-shaped cross section have been shown high performance, future tokamak devices will use elongated plasmas. But at the same time, the more accurate vertical control and prediction are required since elongated plasmas are vertically unstable and cause vertical displacement events (VDEs) as explained schematically in Fig. 1.

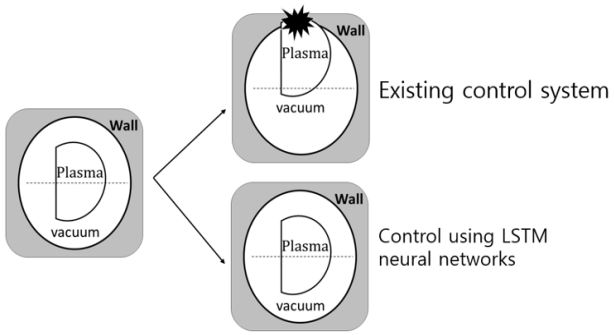

Figure 1 The control of plasma vertical displacement. LSTM based controller has a possibility to control more accurately plasma vertical displacement than existing controller

Tokamaks produce tremendous data every day such as shot data and inspection data such as particle densities, pressure and magnetic field data. These data are important resources for solving the many problems, but there are limitations as humans cannot analyze the enormous data. However, it can be solved by using deep learning schemes. The main reason is that the deep learning can analyze tremendous data by using neural network system. Because neural networks are combination of logistic regression, physical analysis can be done through neural networks. Machine learning is most likely to find hidden rules from the data that the human cannot come up with. This study examines LSTM prediction of plasma vertical displacement by using a compact tokamak device of Plasma with Helical fields Initiative eXperiments (PHiX).

PHiX is designed to research the plasma vertical stability by helical magnetic field created by saddle coils. The PHiX poloidal coil and saddle coil positions also are shown in Fig .2

Table 1 . PHiX parameters

Major Radius R_0	33cm
Minor Radius a	9cm
Plasma Current I_p	< 5 kA
Toroidal field B_t	< 0.3 T
discharge duration t	<5 ms

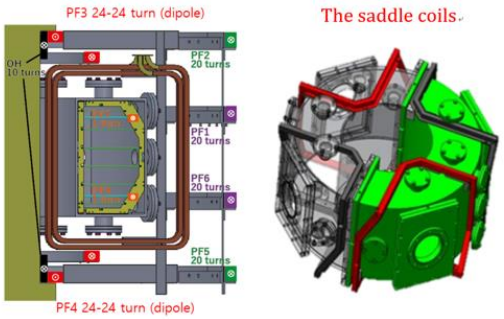

Figure 2. The positions of poloidal colis and saddle coils in the PHiX tokamak.

The purpose of this work is to predict the plasma vertical displacement by using deep learning algorithm. If plasma vertical displacement is predictable by such a method, it can be used to diagnose and control the plasma more efficiently than conventional techniques.

The plasma vertical displacement predictions performed without early stopping model and with early stopping model. Figure 3 shows comparisons between prediction and measured data of plasma vertical displacement. The orange line is prediction and blue line is measured values. We used two models with early stopping and without early stopping training

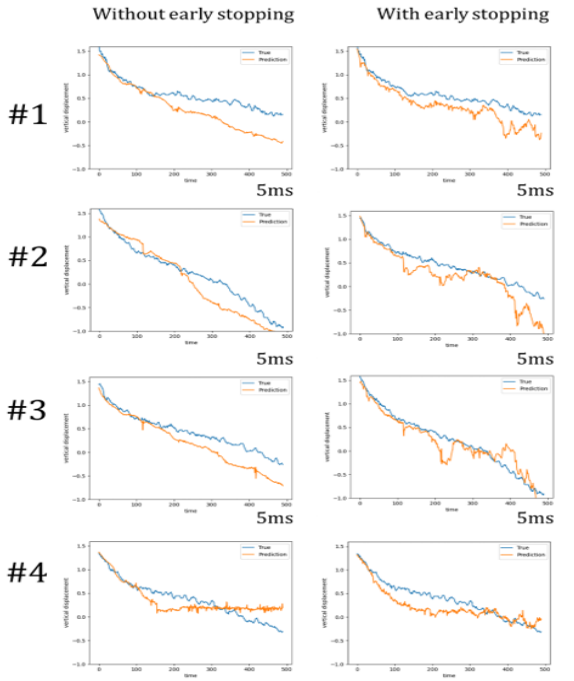

Figure 3. Early stopping and without early stopping training predictions of the vertical displacement #1,2,3,4 by using test data.