論文 / 著書情報
Article / Book Information

題目(和文)	トカマクにおける垂直不安定性を解決するための機械学習技術
Title(English)	Machine Learning Techniques to Solve Vertical Instability in Tokamak
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Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

（博士課程）
Doctoral Program

論 文 要 旨

THESIS SUMMARY

系・コース： Department of, Graduate major in	融合理工学 系 原子核工学 コース	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of （工学 ）
学生氏名： Student's Name	JANG SEJUNG	審査員主査： Chief Examiner	筒井広明

要旨（英文 800 語程度）
Thesis Summary (approx.800 English Words)

Magnetic confinement with tokamaks is one of the attractive nuclear fusion energy schemes for future clean energy production. In the commercial reactor DEMO, an elongated plasma configuration are planned to be used to improve energy confinement time. However, such elongated plasma is vertically unstable and requires precise measurement and control of its vertical position. In DEMO which uses deuterium-tritium fuel, various measurement hardware face limitations due to the neutrons produced by the fusion reactions. To solve these observational limitations, further research focuses on estimating and predicting position of the plasma. This thesis proposes several data-driven methods for the prediction and estimation using operation time series data from Plasma with Helical field initiative eXperiments (PHiX) in Tokyo Institute of Technology, a small tokamak,

Although tokamak is a leading candidate for a fusion power reactor, there remain many problems to be solved for commercial application. Plasma in a tokamak has many instabilities, so various parameters need to be measured and controlled. One approach to solving these problems is by developing a data-driven model using data. Plasma discharge experiment data such as densities, temperature, magnetic field are obtained as time series data from many diagnostic devices such as bolometers, magnetic probes, cameras, and others. Although such measured data obtained from them are important resources for solving the many problems, there are limitations as humans cannot analyze the enormous time series data. However, machine learning methods helps to handle the data. The neural network, which is also one of the machine learning methods, can deal with the enormous amount of data. I use supervised learning and deep learning models for the estimation and prediction of plasma vertical position. In supervised learning, the model learns the patterns by using inputs and outputs referred to as ground truth, which means the correct answers that the model tries to predict.

Estimating plasma vertical position using operational data is crucial for safely controlling elongated plasma and mitigating disruptions linked to Vertical Displacement Events (VDEs), which lead to the influx of impurities and wall damage due to plasma interactions with the wall. In order to solve this problem, machine learning techniques were utilized to develop models that can estimate plasma vertical position. So, a neural network was utilized to create a data-driven model for multivariable regression of plasma vertical position. Time evolution of plasma vertical position is estimated by using long short term memory networks (LSTM) with Time2Vec technique which incorporates temporal information into the neural network. Since many tokamak devices have elongated cross section in achieving high performance whereas accurate vertical position feedback control is required. The data-driven model, using experimental data obtained from a PHiX, can estimate the plasma vertical displacement from operational scenario coils current data. The Time2Vec with LSTM model achieved higher performance than LSTM. In deep learning models, the parameters called weights are adjusted during training. The weights extracted from a trained Time2Vec model can also be interpreted.

Plasma disruptions are one of the problems to be solved in the tokamak, as they cause significant damage to the device and interrupt the discharge. In order to solve the plasma vertical instability related to plasma disruptions, I propose a method based on Natural Language Processing (NLP) models to predict the plasma vertical instabilities. The objective is to identify the precursors, and to forecast plasma vertical displacement within a near future focused on prediction 2 ms ahead in this work. The other objective is the extraction of the data-driven model's weights related to the plasma position. The precursors and associations of the parameters can also be interpreted using Bidirectional Encoder Representations from Transformers (BERT). In this study, BERT, one of the transformer-based models, was applied to a plasma discharge experiment to predict plasma vertical position and to extract the weights that cause plasma displacement, which is difficult with RNNs. In order to use the BERT model with non-language data, a floating point data is discretized and converted to a combination of a word and digits. If a measured value is considered a word, their sequence can be considered as a sentence. By introducing a pseudo-language converted from experimental data, the control and measured parameters related to vertical plasma position can be analyzed by BERT.