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Study of Disruptive Instability Prediction in Tokamaks Through Deep Learning Models

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Introduction

Several scientific and technological challenges need to be overcome for nuclear fusion to become an economically viable energy source. One of these challenges is dealing with instabilities in plasmas, especially those that can lead to severe conditions in the operation of tokamaks. Among these instabilities, disruptive instability, also known as "current disruption," stands out. It is characterized by a sudden and uncontrolled decrease in plasma current, leading to an abrupt termination of the discharge. Artificial Intelligence (AI) has been employed as a significant tool in attempting to assist in solving this issue.

Objective

The aim of this study is to investigate the application of Deep Learning models to predict the occurrence of disruptive instability in Tokamaks. The Tokamak à Chauffage Alfvén Brésilien - TCABR, a small-scale Tokamak belonging to the University of São Paulo (USP), will be the subject of analysis.

Methodology

A comprehensive database of all discharges ever conducted on TCABR is being utilized as the primary source for training and evaluating the selected Deep Learning models for the prediction task. Throughout the study, seven main plasma parameters are being analyzed, such as plasma current, electron density, magnetic fluctuations, among others. This analysis will enable the identification of patterns in the data, facilitating a better understanding of the mechanisms leading to current disruptions in TCABR.

Results

A Deep Rectifier Neural Network (DRNN) was employed for prediction. For the training of the neural network, over two thousand cases were utilized, encompassing both normal and disruptive plasma behaviors. The results obtained using a DRNN were found to be satisfactory, achieving an accuracy of 98.5%.

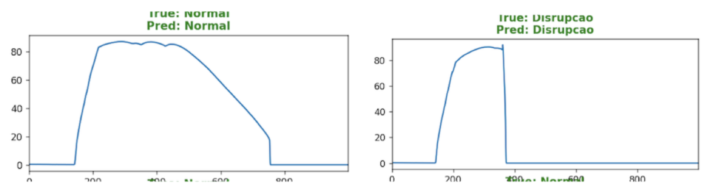

Fig 1. Plasma current classification into normal and disruption.

By utilizing solely the plasma current for the training of the DRNN, it was possible to achieve the prediction of plasma's temporal behavior and identify whether it experienced disruption or not.

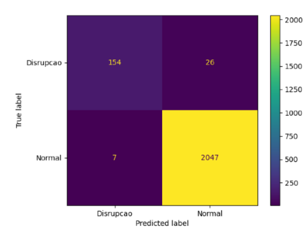

Fig 2. Confusion matrix

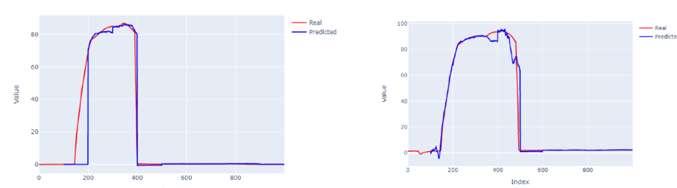

Fig 3. Prediction

Continuing with the project, other neural networks will be employed in an attempt to predict plasma disruption behavior. These networks will be trained using the seven main signals and all discharges from the TCABR reactor's database.

References:
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ZHU, J. X.; REA, C.; MONTES, K.; GRANETZ, R. S.; SWEENEY, R.; TINGUELY, R. A. Hybrid deep-learning architecture for general disruption prediction across multiple tokamaks. Nuclear Fusion, 61(2):1–14, 2020.