Plasma State Classification and ELM detection using Convolutional Long Short-Term Memory Neural Networks

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During a tokamak discharge, the plasma can vary between different confinement regimes, Low (L) and High (H) mode. While it is known that a transition between L and H confinement is achieved once a certain threshold input power is surpassed, the value of this threshold depends on several factors including the configuration of the magnetic field. Furthermore, in some cases, after the threshold has been exceeded, the plasma does not immediately switch state, but can instead be categorized as being in a temporary (intermediate state), called Dithering (D). Another event of interest is the Edge Localized Modes (ELMs). While the plasma is in H mode, ELMs can occur. Several approaches exist for the automatic detection of ELMs. Yet it is also the case that, when looking at time traces, ELMs can be easily confused with Dithering modes. Dithers generally generate much faster oscillations in the signals, while ELMs are mostly characterized by a (momentary) relaxation to the signal baseline. Nevertheless, this distinction can not always be clearly defined.

For these reasons, designing an rule-based system to detect the occurrence of transitions between these modes as well as detection of ELMs is not straightforward. On the other hand, for a human expert, detecting the transitions and ELMs during post-shot data analysis can be achieved with a significant level of accuracy. Nevertheless, this work over a large amount of data comes with significant amount of effort.

This type of scenario is well suited for application of Machine Learning (ML) methods towards enabling automation. However, traditional ML methods typically have limitations when faced with high dimensional data such as the long sequences of samples present in this setting. Recent advances in the ML field with the introduction Deep Learning (DL) approaches deal with exactly such challenges.

Motivated by this we develop a DL based method for automatic detection of the occurrence of L-D-H transitions and ELMs.

In this work we propose a method for encoding the photodiode, interferometer and diamagnetic loop signals. We specify and train a deep neural network model that successfully classifies the transitions and detects the ELMs in the signals. Our model consists of one dimensional convolutional layers that capture the features that arise from the local correlations and recurrent layers that captures the longer term dependencies in the data.

We apply this model on data from the TCV tokamak and evaluate the results using the Sorensen-Dice coefficient and a Confusion Matrix.