DEEP LEARNING FOR PLASMA TOMOGRAPHY AND DISRUPTION PREDICTION

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Abstract

The use of deep learning is facilitating a wide range of data processing tasks in many fields. The analysis of fusion data is no exception, since there is a need to process large amounts of data from the diagnostic systems attached to a fusion device. Fusion data involves images and time series, so they are a natural candidate for the use of convolutional neural networks (CNNs) and recurrent neural networks (RNNs). In this work, we describe how CNNs can be used for image processing to reconstruct the plasma radiation profile. In addition, we describe how RNNs can be used for time series analysis in order to predict plasma disruptions. Both approaches are based on the signals provided by the bolometer system at JET, which is a multi-sensor diagnostic with several lines of sight on a poloidal cross-section of the fusion device. Each bolometer measures the line-integrated radiation along its line of sight.

From the bolometer signals, it is possible to reconstruct the 2D plasma radiation profile using tomography techniques. However, the method that is used at JET is time-consuming, requiring up to 1h to produce a single reconstruction. A CNN trained on existing tomograms can reconstruct the plasma profile with high accuracy, as evaluated by different metrics. It is also much faster, being able to produce 3000 reconstructions per second on a Nvidia Titan X GPU. The same input signals can also be used for disruption prediction. In the bolometer signals, it is possible to observe some of the physical phenomena associated with plasma disruptions. Besides the disruption itself, it is possible to detect, for example, an impurity concentration at the plasma core, which could be the precursor to an impending disruption. A RNN can learn such precursors and become a disruption predictor with comparable performance to those being currently used at JET.

Fig. 1 shows some sample results from both the CNN and the RNN on a JET pulse. The CNN provides the tomographic reconstruction of the plasma profile for a given set of time points. The RNN provides a prediction of the probability of disruption (*prd*) and of the time to disruption (*ttd*) for the same time points. In this example, *prd* is high from early on, since this is a 3 MA high-power pulse. However, *ttd* has a sudden drop when an impurity concentration appears at the plasma core (t = 52.5 s). As soon as $ttd \leq 0.5$ s, an alarm is raised to indicate that a disruption is imminent, with sufficient warning time for mitigating actions. In general, an alarm can be triggered when both *prd* and *ttd* are above/below a certain threshold.

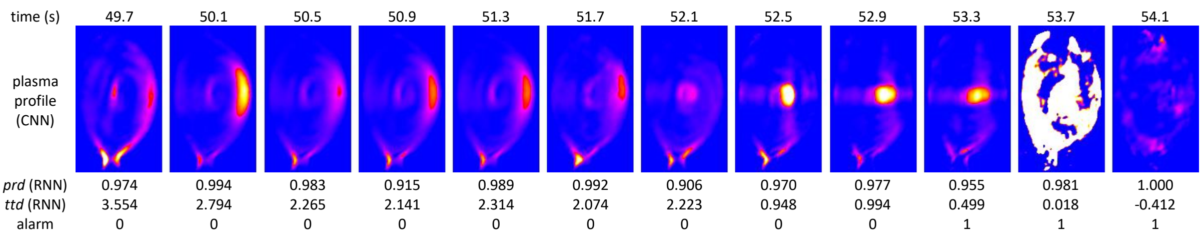

FIG. 1 CNN reconstructions and RNN predictions for JET pulse 92213.