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An interpretable, transferable, and real-time disruption predictor in HL-2A based on deep learning

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A disruption predictor based on deep learning is developed in HL-2A. It has an accuracy of 96.1% on Shot Nos. 32000-36000. Novel 1.5-D CNN + LSTM structure is used to get such a high accuracy. [1] The outputs of algorithm during example disruptive and non-disruptive shots are given in Figure 1. In recent years, further investigations and updates are carried out on the top of the original algorithm, which bring it interpretability, transferability, and real-time capacity.

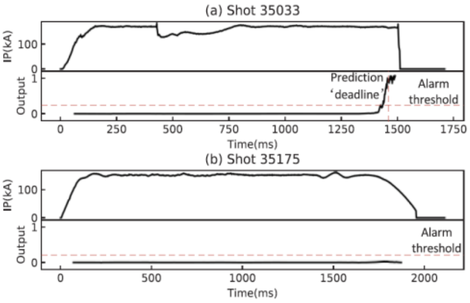

Figure 1 Output of HL-2A's disruption predictor during a disruptive shot (a) and a non-disruptive shot (b).

For the interpretability, HL-2A's algorithm give saliency maps indicating the correlation between the algorithm's input and output. The distribution of correlations in Figure 2 shows good coherence with the disruption causes. A disruption recognizer can be realized by using Bayes theorem to inference disruption reasons by correlations distributions. [2]

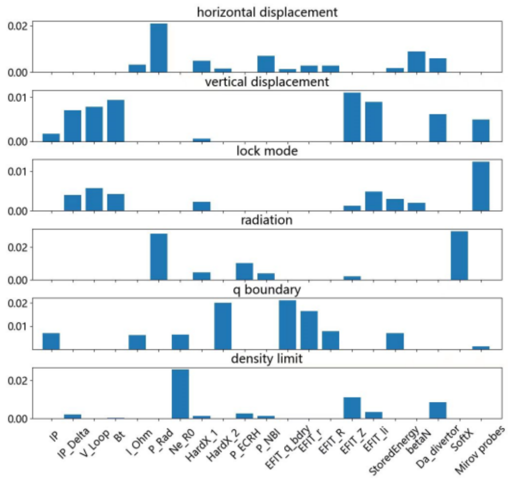

Figure 2 The averaged distribution of input parameter importance for 6 disruption causes in HL-2A.

For the transferability, a preliminary disruption predictor is successfully developed in HL-2M, a newly built tokamak in China. Although only 31 shots are used as the training set of this algorithm, it still gives reasonable outputs with the help of data from HL-2A and J-TEXT, as shown in Figure 3.

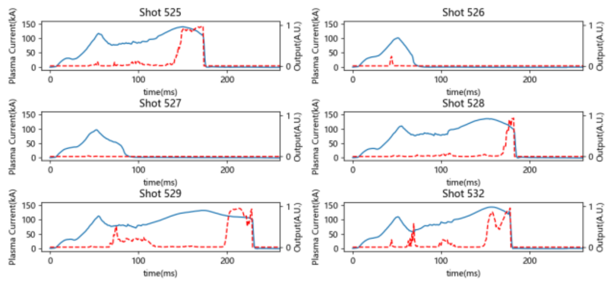

Figure 3 Output of HL-2M's disruption predictor

For the real-time capacity, the algorithm is accelerated to deal with an input slice within 0.3ms with the help of some adjustments on it and TFLite framework. It is implemented into the plasma control system and gets an accuracy of 89.0% during online test. Figure 4 shows the framework of the integrated system and Figure 5 shows a demo shot where the algorithm predicted a disruption and triggered the SMBI to mitigate it. [3]

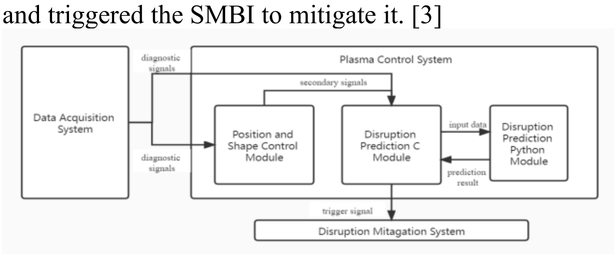

Figure 4 Design of the integrated system

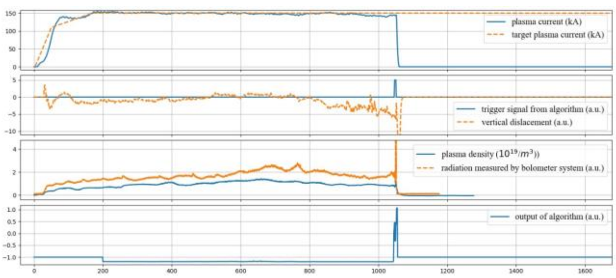

Figure 5 Vertical displacement induced disruption mitigated by SMBI

These three characteristics along with the high accuracy make the deep learning-based disruption predictor in HL-2A a new promising method for the disruption prediction in ITER.

References

[1] Zongyu Yang et al, Nucl. Fusion 60, 016017
[2] Zongyu Yang et al, Nucl. Fusion 61, 126042
[3] Zongyu Yang et al, Fus. Eng. and Des. 182, 113223