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A device-independent pipeline for benchmarking AI-driven disruption prediction models

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Eni strongly relies on the use of Artificial Intelligence (AI) based solutions, with the purpose of progressively making operations more efficient and sustainable, from enhancing safety for personnel to ensuring the integrity of Eni's assets through predictive maintenance solutions and aiding the Research & Development department in crafting innovative technologies to achieve net-zero emissions. In detail, Eni's approach involves developing end-to-end AI solutions, from data collection to model deployment in a production environment. Eni has been actively taking part in magnetic confinement fusion research projects since 2018 by engaging global talent in industrial science and technology and contributing to significant Italian and international initiatives. Eni collaborates with research institutions and provides access to its high-performance computing resources for researchers to model and simulate plasma physics.
The company's expertise in AI and data science has been recently employed to face the significant technological challenge of disruption prediction. Disruptions are harmful for tokamaks and a major concern for next-generation devices. Disruptions must be identified in time and with a suitable advance, allowing the control system to bring the device back into safer and more stable operational regimes (disruption avoidance) or to perform a controlled shut-down of the discharge (disruption mitigation). AI-based approaches have been widely adopted in recent years to address this challenge, leveraging data available from the experimental campaigns of several devices currently operating or which have been in operation in the last decades.
In this framework, we have developed a highly engineered pipeline for developing AI-driven disruption prediction models and relying on industrial data science best practices. Our primary goal is to ensure scalability and reusability across various devices, making it as device-independent as possible. Consequently, this pipeline can effortlessly be adapted to new devices'data with minimal or no adjustments required to the existing code. At this stage, the problem of predicting disruption events has been framed as a binary classification problem and based on the existing Disruption Prediction using the Random Forest (DPRF) model [1,2]. During a shot, the model receives as input features the measurements recorded from different diagnostics [2], processes them, and predicts the "disruptivity", i.e., the probability of being close to disruption. Finally, the disruptivity of consecutive samples is compared against a predetermined threshold. If the disruptivity exceeds this threshold for a specified number of samples, an alarm is triggered.
This pipeline has been validated separately on Alcator C-Mod, DIII-D, and EAST, using publicly available datasets [2,3]. With respect to the results of DPRF [2] we accomplished an overall reduction in terms of both (i) missed alarms at 30ms and (ii) false alarms. This improvement can be attributed to several factors, including a revised data preprocessing approach, different management of class unbalance, and enhancements in the hyperparameter tuning module.
References:
1. C. Rea et al 2019 Nucl. Fusion 59 096016
2. K.J. Montes et al 2019 Nucl. Fusion 59 096015
3. J.X. Zhu et al 2021 Nucl. Fusion 61 026007

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