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Investigating the Physics of the Tokamak Operational Boundaries using Machine Learning Tools

In the last decades, lacking solid and detailed theoretical understanding, machine learning tools have been deployed in various Tokamaks to predict the occurrence of disruptions. Their results clearly outperform empirical descriptions of the plasma stability limits. On the other hand, all the machine learning techniques applied in practice show very poor "physics fidelity"(their mathematical models do not reflect the physics of the underlying phenomena) and limited interpretability. To overcome these limitations, an innovative method is proposed to combine the predictive capability of machine learning tools with the formulation of the operational boundary in terms of traditional mathematical models more suited to understanding the underlying physics. This is achieved by a novel combination of probabilistic Support Vector Machines and Symbolic Regression via Genetic Programming. The results are very positive. The obtained equations of the boundary between the safe and disruptive regions of the operational space classify with about 2.5 % of missed alarms and a similar number of false alarms. The models derived with the proposed data driven methodology therefore present better performance than traditional representations, such as the Hugill or the beta limit, by a significant factor. More importantly, they are compact and easy to grasp mathematical formulas, which are well suited to supporting theoretical understanding and benchmarking of empirical models. For the moment, the developed methodology is used mainly for off line analysis but the derived equations could be easily implemented in real time networks and used in closed loop.

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Track Classification: Prediction and Avoidance