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A comparative study of event detection methods in fusion devices with an application to edge-localized modes

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Event detection will play an increasingly important role for operating fusion devices in a safe and efficient way. In the plasma, various events require detection and identification, such as the onset of magnetohydrodynamic instabilities, appearance of disruption precursors, impurity events, confinement mode transitions, etc. However, in a future fusion power plant, a wide variety of events and faults occurring in general plant systems outside the actual tokamak (e.g. electrical and cooling systems) will also require good, automated detection strategies. To that end, increasingly complex data are being exploited, like time series, images and video, that are obtained from sensors monitoring not only the plasma, but also other plant systems. Once detected and identified, strategies toward prediction, prevention and mitigation need to be deployed in a subsequent stage. In analyzing such data for event detection, the stochasticity of events and their signatures often poses considerable challenges to automated detection techniques. Hence, increasingly sophisticated methods based on probabilistic reasoning and machine learning are needed to detect events, or to estimate the risk of a future occurrence. In this contribution, we present a comparative study of the performance of existing and new event detection methods, applied to the detection of individual edge-localized modes (ELMs) in tokamaks. On the one hand, reliable detection of ELM events is a prerequisite for investigating their properties from a statistical point of view. This is for instance important for risk assessment in the presence of rare, but large ELMs, which can pose a threat to wall components. On the other hand, ELM properties exhibit considerable stochasticity, e.g. in their relative timing and accompanying plasma energy drop. In that sense, they pose a sufficiently challenging case to the detection methods that we have considered in our study. In particular, recent experiments at JET under optimized fueling conditions have led to an operational regime showing great variability of ELM behavior, with small and larger ELMs occurring in irregular time intervals. We compare several state-of-the-art event detection methods with existing techniques. These include robust thresholding methods, time series classifiers using support vector machines, one-dimensional neural networks and object detection methods exploiting feature invariance. Various metrics quantifying the performance of the methods are compared using a dataset of manually labeled ELMs from JET. We propose a number of recommendations towards event detection for future application.

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