Preparation for a Statistical Study of Plasma Disruptions in JET

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PLASMA DISRUPTIONS

• Disruption is a sudden loss of plasma confinement – 100 ms
• Disruptions are characterized by two phases:
  • Thermal Quench – something like half of the thermal energy is lost to the walls
  • Current Quench – plasma current goes to zero
• Combination of thermal and electromagnetic loads can damage the inside of the machine
• No good models exist to predict disruptions because they result from a combination of complex phenomena
  • Locked modes
  • Vertical displacement events
  • Etc.
• For ITER, need to predict with ~98% confidence
• Need to develop machine-portable prediction software
• Machine learning provides powerful tools for data-driven science, complimentary to hypothesis-driven science

SUPPORT VECTOR MACHINES (SVM) [1]

• Classify disruptive vs. nondisruptive states [2,3]
• Plasma state described by diagnostics (e.g. density, current)
• Solve optimization problem to find hyperplane that separates disruptive/nondisruptive states in parameter space
• Use model to classify new data (e.g. live from machine)

SVM CLASSIFIERS

• Classifiers are used to describe the state of the plasma
• Previous work [3] identified 14 classifiers as a baseline
  • 7 Signals
  • Plasma Current [A]
  • Mode Lock Amplitude [T]
  • Plasma Density [m\(^{-1}\)]
  • Radiated Power [W]
  • Total Input Power [W]
  • d/dt Stored Diagnometric Energy [W]
  • Plasma Internal Inductance
  • 2 Representations, consecutive 32 ms intervals
  • mean
  • std(FFT)

MULTI-TIERED SVM [4]

• Analyses 3 consecutive time intervals for better accuracy
• 1\textsuperscript{st} Tier – three models trained with Gaussian Kernel
• 2\textsuperscript{nd} Tier – trained on combined Tier 1 output, Linear Kernel
• Involves a combination of complex phenomena
• Result from a combination of complex phenomena

RECENT WORK AT PPPL

• Extracted 50 GB of signal data from JET MD+plus tree
• Wrote scripts for extracting features from signals
• Developed cross-validation routines for testing SVM
• Rewrote CV routines to be self-contained within Matlab
  • Achieved 100x speedup over use of C++ library
• Participated in Theory and Simulation of Disruptions Workshop to share progress and incite collaboration
• Obtained list of most recent JET disruption data
• Identified SVM model parameters to be used as a baseline
  • 975 d / 975 nd training samples
  • 89.8% success at 30ms before disruption
  • 2% of nondisruptive intervals give false alarms

OBJECTIVES FOR STUDY

• Identify physics-motivated classifiers for prediction
• Multi-dimensional signals, better physics fidelity
• Use as classifiers for threshold tests
• Learn about disruption dynamics
  • Similarities to other phenomena? (L-H transition?)
  • Gain ability to identify precursors (e.g. NTRs)
• Compare experiments to determine software portability
• NSTX-U is right down the hallway!
• Look at parameter scaling between machines
• Possibility of using SVM as backbone for prediction
• Train SVM on outputs of multiple predictors
• Use SVM in parallel with other predictors
• Complexity of predictor limited by availability of computing resources for real-time analysis

NEXT STEPS

• Start to examine signals that have a spatial dimension
• Work on data processing and preparation
• Workshop to share progress and incite collaboration
• Identified SVM model parameters to be used as a baseline

APODIS RESULTS [4]

• Trained with JET carbon-wall data
  • 738 d / 2,035,000 nd samples
• Implemented for real-time operation with ITER-like wall
• 87.5% prediction success at 30ms prior to the disruption

REFERENCES


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