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Applications of Bayesian Data Analysis in KSTAR

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Fusion devices, such as the Korea Superconducting Tokamak Advanced Research (KSTAR) facility, operate under conditions characterized by substantial noise and complexity, necessitating advanced non-invasive diagnostic methods. In recent studies at KSTAR, Bayesian inference techniques are applied to significantly improve the accuracy and reliability of plasma diagnostics. Specifically, Bayesian methods refine plasma edge density profiles by integrating hydrogen beam emission spectroscopy (BES) and two-color interferometry (TCI), resulting in improved resolution and enhanced understanding of edge plasma behavior.
Moreover, a nonnegative Gaussian process tomography framework based on Bayesian inference addresses radiative power losses during plasma disruptions. This approach successfully overcomes the challenges of reconstructing spatial profiles from limited diagnostic data, enabling precise characterization of disruption events and enhancing predictive capabilities.
Additionally, Kalman filter-based data fusion methods integrate magnetic coil and Hall sensor measurements, effectively leveraging the complementary strengths of each sensor type. Bayesian statistics systematically optimize Kalman filter hyperparameters. This combined approach significantly reduces measurement uncertainties and is anticipated to enhance the accuracy of magnetic equilibrium reconstructions, which is crucial for precise plasma control and stable tokamak operation.
Through these applications, Bayesian techniques provide robust solutions to challenges posed by high-dimensional, noisy, and incomplete experimental data, facilitating more accurate plasma characterization and advancing magnetic fusion research.

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