Bayesian Techniques for Optimization of Fusion Diagnostics: A Case Study on the WEST Tokamak

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Abstract

Nuclear fusion devices like tokamaks and stellarators are complex systems operating under extreme physical conditions. As a consequence, direct measurements are typically unfeasible, and diagnostics rely primarily on indirect observations, which inherently present significant inverse problems. Accurate diagnostic systems are therefore critical for obtaining precise magnetic and kinetic information necessary for the reliable operation and safety control of these fusion reactors. However, these diagnostic systems are often constrained by practical limitations such as budget and space restrictions, emphasizing the importance of optimizing their design.

In this study, we present an example of design optimization applied to the pick-up coil diagnostic system on the WEST tokamak, utilizing advanced Bayesian techniques. By employing mutual information as the evaluation metric, we demonstrate that the number of pick-up coils can be substantially reduced without compromising the accuracy of key physical parameters. While Bayesian methods have already proven highly effective in addressing inverse problems such as sensor fusion (integrated data analysis) and solving partial differential equations, this work further shows their strength in system optimization tasks relevant to fusion research.