Bayesian Optimisation using microscopic and integral measurements to infer nuclear data parameters

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Abstract

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1 Introduction

Nuclear data is considered as the major source of uncertainty in some reactor observables, most notably effective multiplication factor (k_{eff}). The nuclear data available in evaluated nuclear data libraries, such as JEFF-4.0, are a result of a complex fitting procedure including theoretical models, microscopic experiments and expert judgement. Integral experiments are then used to assess the performance of the nuclear data. In this work, a novel Bayesian Optimization (BO) framework is proposed which enables consolidating microscopic energy dependent measurements with integral experiments to estimate nuclear data parameters.

The BO is performed using a Markov Chain Monte Carlo method in which surrogates are used to evaluate the likelihoods. For the microscopic energy dependent measurements, the SAMMY v8.1.0 resonance fitting tool [1] is employed. While SERPENT v2.2.2 [2], a Monte Carlo neutron transport code, is used to quantify the integral response. Surrogates are trained by evaluating random samples drawn in the input space in the high-fidelity models. The methodology is tested on two case studies, being ^{53}Cr and ^{238}U. Since microscopic experiments often provide many thousands of points and integral experiments only provide a single points, care is given to analyze how different weighing factors affect the results.

2 Background and mathematical motivation

2.1 Bayesian Inference setup

The main objective of this paper is to infer nuclear data parameter(s) from a set of both microscopic energy dependent an integral experiments. Microscopic energy dependent measurements, further noted as microscopic measurements, are measurements which return a measurement for a well defined energy. Often such measurements result from neutron Time-Of-Flight (nTOF) facilities in which the energy of the neutron is derived from the time it takes for the neutron to reach a target. Typical of these measurements is the many different points that are obtained. In contrast, integral measurements such as criticality experiments, only provide one value which is representative of a group of nuclides, reactions and energies. According to Bayes theorem, the posterior (updated) probability density finction (PDF), $P(\text{data}|\theta)$, is proportional to the likelihood of observing the data given the parameter(s) θ multiplied by the prior belief of the parameter(s):

$$P(\text{data}|\theta) \propto P(\theta|\text{data}) \cdot P(\theta) \tag{1}$$

2.2 Surrogate modelling

2.3 Markov Chain Monte Carlo (MCMC)

2.4 Likelihood Formulation

3 Results

3.1 Chromium-53

3.2 Uranium-238

4 Discussion

5 Conclusions and future work

References

[1] N. M. Larson, "Updated User's Guide for Sammy: Multilevel R-Matrix Fits to Neutron Data Using Bayes' Equations."

[2] J. Leppänen, M. Pusa, T. Viitanen, V. Valtavirta, and T. Kaltiaisenaho, "The Serpent Monte Carlo code: Status, development and applications in 2013," *Annals of Nuclear Energy*, vol. 82, pp. 142–150, Aug. 2015.