Inverse Problems for Stochastic Neutronics

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Abstract:

Fissile matter detection and characterization is a crucial issue; especially in nuclear safety [3], reactivity measurements, monitoring of sub-critical reactors. In this context, we want to identify a source of fissile matter knowing external measures such as detection times of neutrons during a long time interval $[0, T_{meas}]$.

The problem is the following one, we observe the neutron detection times of neutrons emitted by the source and going through the detector [2], then we compute the moments of the empirical distribution of the number of neutrons detected during a time gate T.

In order to identify the source we have to estimate the following parameters: ρ the reactivity of the system, S the intensity of the source, x the proportion of compound Poisson source, and ε_F the fission efficiency.

Given the parameters of the source there are models that allow us to predict the moments of counted number of neutrons during a time gate T. During the Manhattan project (1939-1946) R. Feynman established a point model which relates the excess of count number variance to a nuclear parameter of interest. The method was extended to higher order moments of count number distribution: neutron physicists usually take into account the three first moments (since the estimation of the fourth moment is noisy).

Then, given observations (i.e. the empirical moments of counted number of neutron during a time gate T) we want to estimate the parameters of the fissile source. In order to achieve this goal, we can use two different approaches

- least square error estimation: By minimizing the mean square error between the empirical moments and the theoretical moments of the point model, we get an estimator of the parameters. We use simulated annealing to solve minimization problem.
- Bayesian estimation in order the get the a posteriori distribution of the parameters [6]. This distribution is non-trivial, samples can be achieved with Markov Chain Monte-Carlo methods (MCMC) [5].

Synthetic data can be generated by MCNP6 or Tripoli-4 codes and used to test the estimation methods.

Keywords—inverse problems, random neutronics, bayesian methods, simulated annealing

References

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Short biography – Coming from Nantes University with fundamental and applied masters, I found a PhD with CEA in uncertainty quantification for random neutronics. The aim of my work is focused on determining the nuclear parameters for safeguard using Bayesian methods.