Towards an Interval Particle Transport Monte Carlo Method[*]

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Neutronics is the study of how neutrons propagate through matter: how they interact, what with, and their manipulation; and is of central importance to the operation of a nuclear reactor, fission or fusion. Monte Carlo has for a long time been the high fidelity method of choice for Neutronics, due to its simplicity and its ability to handle complicated geometries. Recently there has been a growing interest in the quantification and propagation of uncertainty in these types of calculation. Most of these methods are for nuclear data uncertainty propagation, and are mostly either perturbation theory or sensitivity based methods [1]. These methods have been effective for fission, but are yet to be successful for fusion applications due to the severity of the uncertainty and high number of variables that must be considered.

The current state of the art in uncertainty propagation in particle transport is the so called Total Monte Carlo method [5], a method which relies on the repeated execution of the same transport simulation. This however is often computationally intractable even with modern high performance computing standards (a full reactor simulation would require the simulation of $\sim 10^{12}$ particles). In this project we explore alternatives to Total Monte Carlo for uncertainty propagation in neutron transport, which can yield a robust measure of uncertainty at a reduced computational cost.

The method proposed in this work is based on probability bound analysis [2, 4], where the neutronics model is altered to include uncertainty as a part of the physics calculation, removing the need for the above-mentioned Monte Carlo. Neutron attributes (position, energy, direction) are intervals, representing the uncertainty in the neutron's state at each point in its history. The stochastic drivers (the distributions which determine the neutron's next state) are p-boxes, which are sampled to produce random intervals. By simulating a large number of imprecise neutron histories, uncertainty can be propagated in a single model evaluation, albeit a more expensive simulation. The interplay of stochasticity (from the stochastic neutronics model) and epistemic uncertainty (from the unknown inputs to the model) produces p-boxes as outputs. By repeating the stochastic simulation multiple times with interval inputs, a distribution of intervals is created from which a p-box is fit [3].

References

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