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Stabilization of Monte Carlo Fission Source Distribution in p-CMFD Acceleration Method

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1. Introduction

The acceleration method for source convergence in Monte Carlo (MC) k-eigenvalue problem by the partial current-based Coarse-Mesh Finite Difference (p-CMFD) deterministic method [1] was proposed by Yun and Cho [2], in which the coarse-mesh fission source distribution (FSD) from p-CMFD solution is fed back as weight adjustment in the next-cycle MC simulation and its efficacy was demonstrated in heterogeneous continuous-energy problems. They observed that stochastic errors in p-CMFD parameters cause larger fluctuations in FSD during acceleration compared to the fluctuations in conventional method. To overcome this problem, they proposed in the same work accumulation of the p-CMFD parameters over the entire inactive cycles. However, accumulation of the p-CMFD parameters including too early cycles causes bias in FSD and consequently degrades the acceleration speed.

In a similar work of coarse mesh finite difference (CMFD) acceleration of multi-group Monte Carlo calculation [3], Lee et al. proposed a multi-set scheme [4]. It accumulates the CMFD parameters that are reset with a certain frequency (e.g., every 5 cycles). They successfully tested the multi-set scheme in 3-D multi-group core problems.

In this paper, in the context of p-CMFD acceleration of continuous-energy Monte Carlo k-eigenvalue problem [2], two variations of the accumulation schemes are described and compared with the previous accumulation schemes in a 1-D continuous-energy thermal reactor test problem.

2. Accumulation Schemes

2.1 Scheme 1

We define a group of MC cycles as a packet. During the first packet (e.g., Cycle 1~5), p-CMFD parameters are generated for each cycle and used for p-CMFD acceleration but not accumulated in Scheme 1. After the first packet of cycles, the parameters are accumulated as usual throughout the inactive cycles [2]. Skipping accumulation during the first packet reduces bias in the averaged p-CMFD parameters significantly.

2.2 Scheme 2

Similar to Scheme 1 in Section 2.1, p-CMFD parameters are not accumulated during the first packet in Scheme 2. But after the first packet of cycles, the parameters are enqueued in a *First In First Out* (FIFO) queue which has certain length (e.g., 5). The averaged p-CMFD parameters are calculated with the values stored in queue and used for p-CMFD acceleration for each cycle. When the queue is full, the oldest p-CMFD parameters are dequeued and the new ones are enqueued as shown in Fig. 1.

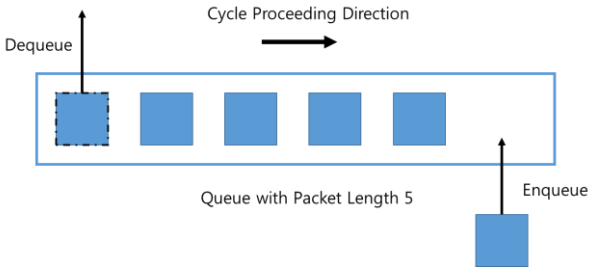

Fig. 1. FIFO queuing scheme

3. Numerical Results

A 1-D thermal reactor test problem shown in Fig. 2 is solved by continuous-energy MC calculation using McSLAB [5] and source convergence is accelerated by p-CMFD method. MC and p-CMFD calculation conditions are shown in Table I. To compare effectiveness of the accumulation schemes, 30 independent batch runs are performed. Figs. 3 and 4 show the sample mean and standard deviation of Shannon entropy [6] of the FSD for each cycle obtained in each scheme. Reference Shannon entropy is obtained from the 30 independent batch runs of conventional MC calculation consisting of 200 inactive cycles and 50 active cycles

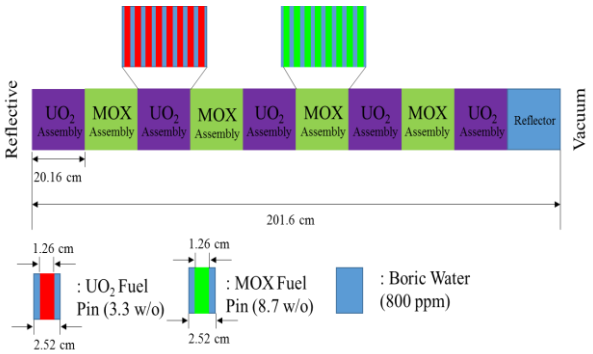

Fig. 2. 1-D thermal reactor test problem

Table I. MC and p-CMFD calculation conditions

Monte Carlo Calculation		p-CMFD Calculation	
No. of Histories per Cycle	2×10^5	No. of Energy Groups	2
Initial Guess for FSD	Uniform distribution	Coarse-Mesh Size	10.08 cm

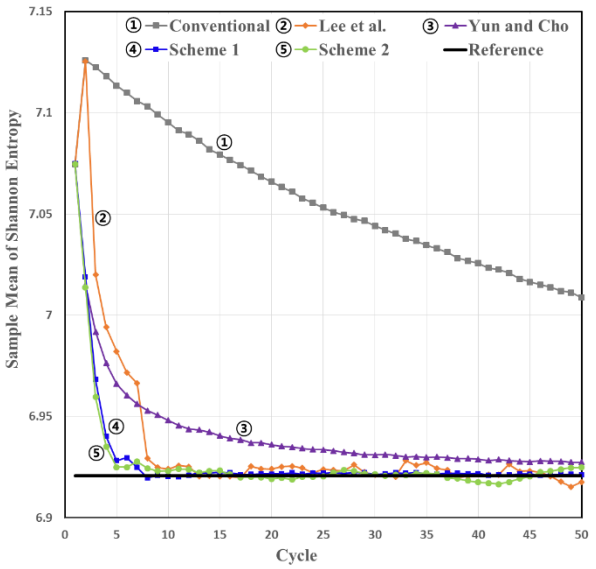

Fig. 3. The sample means of Shannon entropies obtained from 30 independent batch runs

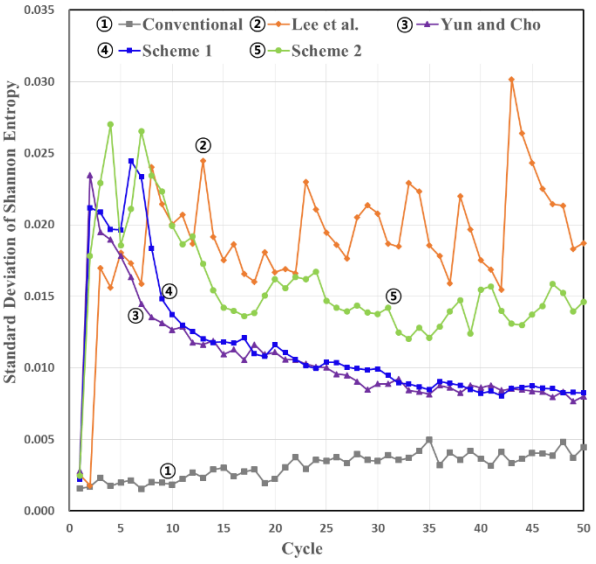

Fig. 4. The standard deviations of Shannon entropies obtained from 30 independent batch runs

From Fig. 3, it is seen that the means of Shannon entropies of Scheme 1 and 2 converge to reference faster than other accumulation schemes due to the skipping of accumulation during the first packet. For the standard deviations of Shannon entropies in Fig. 4, Scheme 1 and 2 show large standard deviations until around Cycle 10. After that, they give smaller values than Lee et al.'s scheme (as implemented in p-CMFD acceleration). Both Scheme 1 and Yun and Cho's scheme show much smaller standard deviations than other accumulation schemes, but Yun and Cho's scheme shows slow convergence and some bias in Shannon entropy remains throughout cycles.

4. Summary and Conclusions

To stabilize the fluctuations in MC FSD obtained from p-CMFD acceleration, two accumulation schemes which exclude the first packet from accumulation are proposed. One is a scheme accumulating the p-CMFD parameters in the remaining entire inactive cycles (Scheme 1) and another is FIFO queuing scheme (Scheme 2). For the 1-D continuous-energy thermal reactor test problem, Scheme 1 shows the best result in terms of stabilizing effect on FSD among the accumulation schemes considered in this study. The initial packet length to be excluded from the accumulation should depend on the problem on hand, but it could be determined by good engineering insight for the typical reactor problems.

Acknowledgment

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