Aalto University
School of Science
and Technology

Monte Carlo method in particle transport simulations
Lecture 5 – Bonus round

Jaakko Leppänen

Department of Applied Physics
Aalto University, School of Science
Jaakko.Leppanen@aalto.fi

Nov. 10, 2020

Bonus round

The last round of exercises includes no new theory or mandatory tasks. Extra points are awarded by completing bonus tasks, which may require some independent studies.

Complete at least one task in round 5. No separate deadline for exercise round 4, but complete the tasks before starting to work on round 5.

We'll arrange one more Zoom meeting, where each course participant presents their work:

- $\sim$20 min reserved for each presentation
- Overview of methods and implemented solutions in your MC code
- Present selected results of exercises that you found particularly interesting (focus on the last two exercise rounds)
- Other comments on course content (what you found interesting, what was difficult, suggestions for improvement, etc.)

The final deadline is flexible, options:

- The last official lecture is on December 1st (too early?)
- We can also set up a later date by Doodle. If the date is postponed to January and you need the credits by the end of the year, you can also write a more formal final report.

Bonus round

Bonus task 1 – Source code optimization (2p)

Demonstrate significant improvement in computational efficiency by optimizing your source code.

Bonus task 2 – Parallelization (3p)

Implement parallel calculation capability based on OpenMP or MPI methodology. Demonstrate significant parallel scalability of running time.

Bonus task 3 – Implicit Monte Carlo and variance reduction (2-6p)

Implicit Monte Carlo and variance reduction techniques are described in Lux & Koblinger. Implement implicit capture (2p) and/or a variance reduction scheme based on cell importances or weight-windows (4p).

The methodology should be demonstrated by a streaming problem, in which neutrons are emitted by a point source in an infinite medium of water, and flux and total collision rate is evaluated as function of distance from the source point. The purpose of the implicit techniques is to obtain improved statistics far from the source without biasing the results.

Bonus task 4 – Independent design task (2-6p)

Plan and implement a design task for your Monte Carlo code. Present the modeled problem and the implemented solution.

Bonus round

Bonus task 5 – Reactor design (5p)

Design a reactor consisting of natural uranium and a moderator/reflector of your choice in a heterogeneous configuration. Optimize the design in such way that the system becomes critical at room temperature with the lowest possible amount of uranium (and reasonable amount of other materials). Calculate the fuel-to-moderator volume ratio.

Cross sections for light- and heavy water and graphite are available at:

`http://virtual.vtt.fi/virtual/montecarlo/misc/PHYS-E0565/`

Other cross sections are available by request. Calculate results that you think are relevant for the task.

Bonus task 6 – Doppler benchmark (3p)

Repeat the calculation exercise in:

> R. Mosteller, et al. *"Benchmark calculations for the Doppler Coefficient of Reactivity."* Nucl. Sci. Eng., **107** (1991) 265–271.

The paper and cross sections are available at:

`http://virtual.vtt.fi/virtual/montecarlo/misc/PHYS-E0565/`

NOTE: Obtaining sufficient statistics for k_{eff} may require running a large number of neutron histories. If your code is terribly slow, repeat the calculation only for enrichments 0.711, 2.4 and 3.9 wt% ^{235}U. Compare your results to the results reported in the paper.

Bonus round

Bonus task 7 – Additional reactivity coefficients (3p)

Calculate additional coefficients for the previous Doppler benchmark problem with 2.4 wt% fuel:

- Moderator density coefficient (using 10% reduction in moderator density)
- Moderator temperature coefficient (using 20 degree increase in free-gas temperature)
- Boron coefficient (reduction of 20% in coolant boron concentration)

Report the results similar to the Doppler coefficient (pcm reactivity defect divided by unit variation in parameter value). Increase the magnitude of the variation if the differences in k_{eff} are too small compared to statistical accuracy, but try to stay within reasonable limits.

Repeat the three previous calculations + Doppler for MOX fuel with the following composition (in atom/b·cm): ^{238}U: 2.1037E-02 / ^{239}Pu: 8.3501E-04 / ^{240}Pu: 2.5798E-04 / ^{241}Pu: 9.4430E-05 / ^{16}O: 4.4678E-02. Explain the differences compared to the uranium fuel.

Evaluate the effect of fuel-to-moderator volume ratio on moderator density coefficient for the 2.4 wt% uranium fuel. Modify the geometry by gradually increasing the pin-cell pitch. Explain the trend.

Evaluate the effect of coolant boron concentration on moderator density coefficient for the 2.4 wt% uranium fuel. Modify the coolant composition by gradually increasing the boron concentration. Explain the trend.