Differences in Batch Versus History Statistics

Aislinn Hamilton, Tristan Razote, Nadia Robinson, Zach Starnes
Appalachian STEM Academy at Oak Ridge 2022

Introduction

With supercomputers becoming more and more used for various fields, like nuclear engineering and physics, science needs to improve our methods for using these supercomputers for more precise calculations. What is faster and more accurate when calculating the neutron uncollided flux using the Monte Carlo method: batch or history statistics?

Hypothesis

When solving the Boltzmann radiation transport equation using the Monte Carlo method, **batch statistics are more accurate for dose tallies than history statistics.**

Figure 2: Team working on hypothesis

Background

- The new Graphics Processing Unit (GPU) architectures used for modern models of supercomputers allow for faster and more parallel calculations.
- Monte Carlo method is a general idea of statistics based on using experiments where random variables are allowed to affect the outcomes.
- Batch statistics is a method of calculating particles by looking at their events, collisions, and changes in the system. Batch statistics separate the particles by their group allowing the computer to track them more efficiently.
- History statistics is a method of tracking particles by looking at the whole life of the particle in the system. History statistics simulate the individual particles from many different outcomes which can be inefficient on computers.

Figure 1: Frontier supercomputer

Materials

- Python
- Jupyter Notebook
- HP Intel core i3
- **Operator equation**

$$(L\psi = S\psi + q)$$

Methods

Use the Monte Carlo method to run simulations.

Change particle and batch numbers to simulate Batch or History statistics

```
def run(point, shape, delta, sigma, strength, Nbatches, Nparticles):

    mesh    = uf.Mesh(shape=shape, delta=delta, sigma=sigma)
    source = uf.Source(point=point, strength=strength)
    uncf    = uf.MCUNCF(source=source, mesh=mesh)

    uncf.Nb = Nbatches
    uncf.Np = Nparticles

def go(point):
    flux, error, btc = run(point,(17,17,17),(0.5,0.5,0.5),1.0,1.0,20,500)

    print()
    print(btc)
    print(btc.sum(axis=0))

    return flux, error
```

Figure 4: Sample of python code used

Return the neutron population and total particles that have hit their target.

Create a graph to track the flux accuracy.

From the graph, analyze the relative error of neutron flux.

Compare results

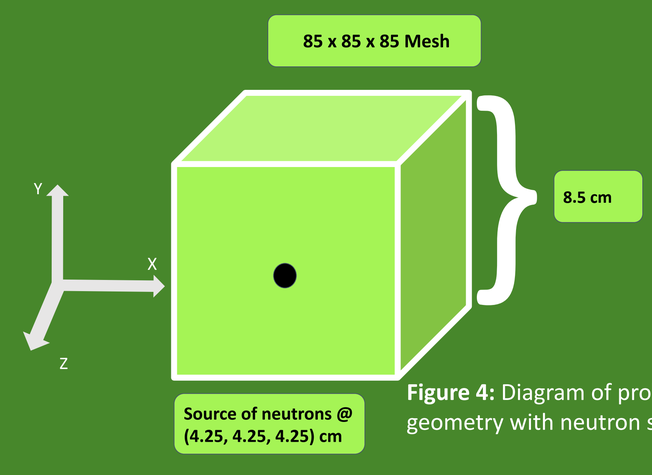

Figure 4: Diagram of problem geometry with neutron source

This is a visual representation of what the python code is doing. Neutrons are released from the center of the mesh.

Figure 5: Tara Pandya (Back), (left to right)Nadia Robinson, Aislinn Hamilton, Tristan Razote, Zach Starnes

Results

Batch

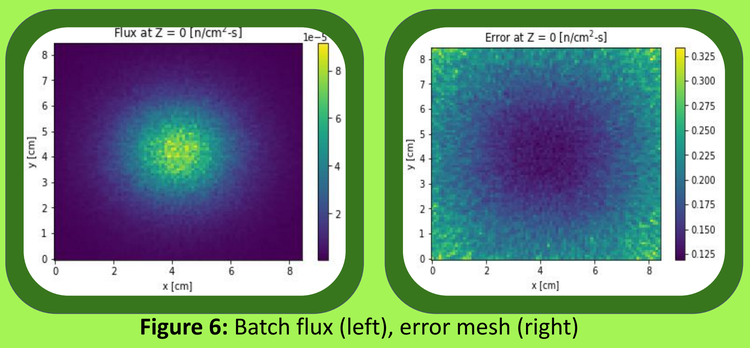

Figure 6: Batch flux (left), error mesh (right)

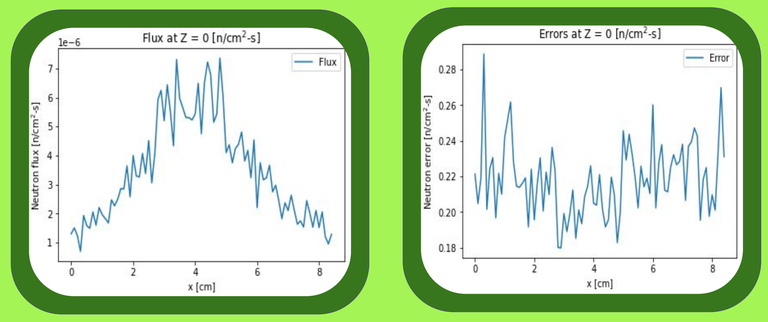

Figure 7: Batch flux y=0, z=0 (left), error line plot y=0, z=0 (right)

History

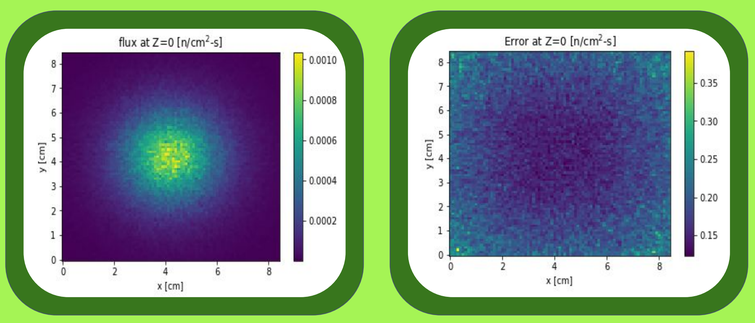

Figure 8: History flux (left), error mesh (right)

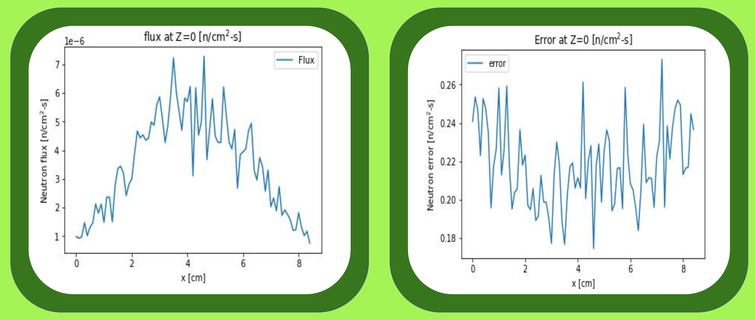

Figure 9: History flux, y=0, z=0 (left), error line plot, y=0, z=0 (right)

Conclusions

- Batch based statistics are more accurate than history based statistics.
- The future of supercomputer calculations should be based around examining the specific instances in which events occur and track information based on that to accommodate for GPU based systems.

Acknowledgements

We appreciate the opportunity provided to us by Oak Ridge National Laboratory, Oak Ridge Associated Universities and the Appalachian Regional Commission. Thank you to our mentors, Dr. Tara Pandya, and Dr. Tom Evans.

References

Hamilton, S. P., & Evans, T. M. (2019, January 17). Continuous-energy Monte Carlo neutron transport on GPUs in the Shift code. Annals of Nuclear Energy. Retrieved July 19, 2022, from https://www.sciencedirect.com/science/article/pii/S0306454919300167

"The Ultimate Fast Facts Guide to Nuclear Energy." Ultimate Fast Facts Guide, https://www.energy.gov/sites/default/files/2019/01/f58/Ultimate%20Fast%20Facts%20Guide-ebook_1.pdf.

Neutron transport. (2022, April 19). Wikipedia. https://en.wikipedia.org/wiki/Neutron_transport

The Ultimate Fast Facts Guide to Nuclear Energy. (n.d.). Energy.gov. https://www.energy.gov/ne/articles/ultimate-fast-facts-guide-nuclear-energy