LAWRENCE
LIVERMORE
NATIONAL
LABORATORY

LLNL-ABS-791198

Extending 1D Transport Using Neural Nets to GPUs

M. M. Pozulp, P. S. Brantley

September 24, 2019

Joint International Conference on Supercomputing in Nuclear Applications + Monte Carlo 2020
Tokyo Metropolitan Area (Chiba), Japan
May 18, 2020 through May 22, 2020

Extending 1D Transport Using Neural Nets to GPUs

Michael M. Pozulp
University of California, Davis, and
Lawrence Livermore National Laboratory
7000 East Ave, L-170
Livermore, CA 94550
pozulp1@llnl.gov

Patrick S. Brantley
Lawrence Livermore National Laboratory
7000 East Ave, L-170
Livermore, CA 94550
brantley1@llnl.gov

ABSTRACT

Production transport codes at Lawrence Livermore National Laboratory (LLNL) typically use either Monte Carlo (MC) or discrete ordinates (S_N) to solve the transport equation on supercomputers. Efforts are underway to port both capabilities to graphics processing units (GPUs) for Sierra, a hybrid CPU-GPU computer, where the majority of the FLOPS and memory bandwidth come from the GPUs [1]. LLNL has achieved an order of magnitude speedup for S_N [2] [3]. History-based implicit Monte Carlo thermal photon transport has exhibited modest GPU speedups [4], while work to overcome a slowdown exhibited by history-based MC neutronics is ongoing [5].

Part of the problem contributing to the MC neutronics slowdown is that GPUs were not designed to solve the transport equation. GPUs are designed for fast, power-efficient execution of linear algebra operations found in graphics rendering and neural network training. The neutron transport equation can be solved using a neural network (NN), but existing work demonstrating the NN solution is limited to simple 1D problems with analytic solutions and did not employ GPUs [6] [7] [8].

In this work, a GPU is used to solve the transport equation using a NN, and the solution is compared to S_N and MC. The goal is not to replace S_N and MC - both will remain production capabilities for the foreseeable future at LLNL. Instead, the goal is to provide a foundation on which hybrid methods employing NNs in combination with S_N or MC may be considered in the future.

KEYWORDS: neural network, 1D transport, GPU

REFERENCES

[1] S. S. Vazhkudai, B. R. de Supinski, A. S. Bland, A. Geist, J. Sexton, J. Kahle, C. J. Zimmer, S. Atchley, S. Oral, D. E. Maxwell, V. G. V. Larrea, A. Bertsch, R. Goldstone, W. Joubert, C. Chambreau, D. Appelhans, R. Blackmore, B. Casses, G. Chochia, G. Davison, M. A. Ezell,

T. Gooding, E. Gonsiorowski, L. Grinberg, B. Hanson, B. Hartner, I. Karlin, M. L. Leininger, D. Leverman, C. Marroquin, A. Moody, M. Ohmacht, R. Pankajakshan, F. Pizzano, J. H. Rogers, B. Rosenburg, D. Schmidt, M. Shankar, F. Wang, P. Watson, B. Walkup, L. D. Weems, and J. Yin. "The Design, Deployment, and Evaluation of the CORAL Pre-exascale Systems." *Proceedings of the International Conference for High Performance Computing, Networking, Storage, and Analysis*, pp. 52:1–52:12 (2018).

[2] A. Kunen, J. Loffeld, A. Black, R. Chen, P. Nowak, T. Haut, T. Bailey, P. Brown, S. Rennich, P. Maginot, and B. Tagani. "Porting 3D Discrete Ordinates Sweep Algorithm in Ardra to CUDA." *International Conference on Mathematics and Computational Methods applied to Nuclear Science and Engineering (M&C)*, pp. 2585–2598 (2019).

[3] P. Nowak, A. Black, S. Rennich, D. Appelhans, R. Chen, T. Haut, P. Maginot, T. Bailey, P. Brown, A. Kunen, J. Loffeld, and B. Tagani. "Porting Teton, a Discrete-Ordinates Thermal Radiative Transfer Code, to Sierra." *International Conference on Mathematics and Computational Methods applied to Nuclear Science and Engineering (M&C)*, pp. 2128–2137 (2019).

[4] P. S. Brantley, N. A. Gentile, M. A. Lambert, M. S. McKinley, M. J. O'Brien, and J. A. Walsh. "A New Implicit Monte Carlo Thermal Photon Transport Capability Developed Using Shared Monte Carlo Infrastructure." *International Conference on Mathematics and Computational Methods applied to Nuclear Science and Engineering (M&C)*, pp. 564–577 (2019).

[5] M. S. McKinley, R. Bleile, P. S. Brantley, S. Dawson, M. O'Brien, M. Pozulp, and D. Richards. "Status of LLNL Monte Carlo Transport Codes on Sierra GPUs." *International Conference on Mathematics and Computational Methods applied to Nuclear Science and Engineering (M&C)*, pp. 2160–2165 (2019).

[6] P. S. Brantley. "Artificial Neural Network Solutions of Slab-Geometry Neutron Diffusion Problems." *Transactions of the American Nuclear Society*, (83), p. 251 (2000).

[7] P. S. Brantley. "Spatial Treatment of the Slab-geometry Discrete Ordinates Equations Using Artificial Neural Networks." Technical Report UCRL-JC-143205, Lawrence Livermore National Laboratory, Livermore, California (2001).

[8] M. M. Pozulp. "1D Transport Using Neural Nets, SN, and MC." *International Conference on Mathematics and Computational Methods applied to Nuclear Science and Engineering (M&C)*, pp. 876–885 (2019). http://mike.pozulp.com/2019nnPaper.pdf.