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Challenges and opportunities integrating LLAMA into AdePT

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Particle transport simulations are a cornerstone of high-energy physics (HEP), constituting almost half of the entire computing workload performed in HEP. To boost the simulation throughput and energy efficiency, GPUs as accelerators have been explored in recent years, further driven by the increasing use of GPUs on HPCs. The Accelerated demonstrator of electromagnetic Particle Transport (AdePT) is an advanced prototype for offloading the simulation of electromagnetic showers in Geant4 to GPUs, and still undergoes continuous development and optimization. Improving memory layout and data access is vital to use modern, massively parallel GPU hardware efficiently, contributing to the challenge of migrating traditional CPU based data structures to GPUs in AdePT. The low-level abstraction of memory access (LLAMA) is a C++ library that provides a zero-runtime-overhead data structure abstraction layer, focusing on multidimensional arrays of nested, structured data. It provides a framework for defining and switching custom memory mappings at compile time to define data layouts and instrument data access, making LLAMA an ideal tool to tackle the memory-related optimization challenges in AdePT. Our contribution shares insights gained with LLAMA when instrumenting data access inside AdePT, complementing traditional GPU profiler outputs. We demonstrate traces of read/write counts to data structure elements as well as memory heatmaps. The acquired knowledge allowed for subsequent data layout optimizations.

Significance

AdePT is central to the current strategy for improving simulation throughput in Geant4. We contribute further optimizations to the project. By coupling these optimizations with LLAMA, a general-purpose library, the demonstrated strategies, insights and optimizations will be transferable to other projects targeting GPUs and heterogeneous systems as well.

References

AdePT at ACAT2021: https://indico.cern.ch/event/855454/contributions/4605037/
LLAMA paper: https://doi.org/10.1002/spe.3077

Experiment context, if any

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