GCLab

Performance Portable Plasma Simulations for the Exascale Era

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Project Description

Vector Particle-In-Cell (VPIC) is a high performance plasma simulation code capable of scaling to the largest supercomputers in the world. VPIC has been optimized for CPU and Many-core architectures but the recent diversifying of hardware magnifies the challenge. To keep up with the rapid growth in hardware, we ported VPIC using the Kokkos performance portability framework. This project quantifies performance and power tradeoffs that portability frameworks like Kokkos introduce. We use this information to better optimize VPIC application across multiple platforms including Power9. The initial port already achieves near ideal weak scaling on 2,048 Summit nodes with 12,288 GPUs.

Motivation

As we approach exascale computing the variety of architectures continues to expand. This makes porting and optimization very difficult. Using a portability framework like Kokkos alleviates these issues but the tradeoffs introduced have not been quantified. This project aims to explore the tradeoffs and optimization strategies involved when working with portability frameworks.

Supercomputer	CPU	Accelerator
Summit/Sierra	Power9	Tesla V100
Trinity	Xeon	Xeon Phi
Perlmutter	Epyc	Tesla
Aurora	Xeon	Intel Xe
Frontier	Epyc	Radeon

Performance Portability

To quantify performance portability we use the metric outlined by Pennycook[1]. The score is defined as follows

$$\Phi(a,p,H) = \begin{cases} \dfrac{|H|}{\sum_{i \in H} \dfrac{1}{e_i(a,p)}} & \text{if } i \text{ is supported } \forall i \in H \\ 0 & \text{otherwise} \end{cases}$$

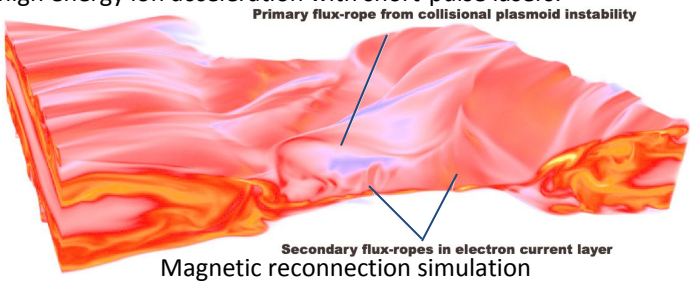
Where H is the set of platforms, a is the application, p is the problem, and $e_i(a,p)$ is the performance efficiency. Application efficiency (achieved as a fraction of best observed performance) is used as the efficiency metric.

VPIC Version	Φ(CPU) App. Eff.	Φ(GPU) App. Eff.	Φ(All) App. Eff.
Base	61.26%	0%	0%
SIMD	100%	0%	0%
Kokkos	48.89%	100%	52.74%

1. Pennycook, Simon J. et al. “A Metric for Performance Portability.” ArXiv abs/1611.07409 (2016): n. pag.

VPIC

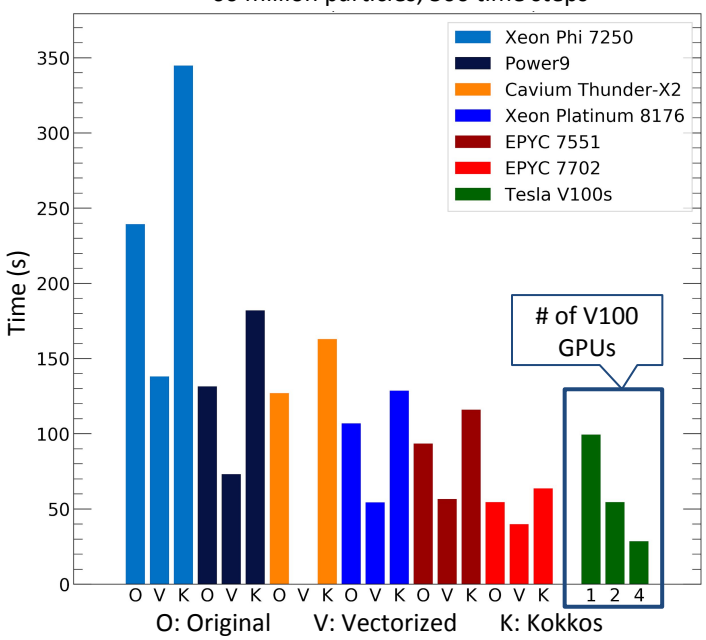
The Vector Particle-In-Cell (VPIC) project is a state of the art particle-in-cell code that is noteworthy for its high performance. VPIC is used for relativistic plasma simulations such as laser-plasma interactions in fusion experiments and high energy ion acceleration with short-pulse lasers.



Magnetic reconnection simulation

VPIC with and without Kokkos

~66 million particles, 500 time steps



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