Can memory-bound code benefit from the great power of GPUs?

— Acceleration of a 3D high-order Finite-Difference WENO Scheme for Large-Scale Cosmological Simulations on GPU

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What is WENO?

Weighted essentially non-oscillatory (WENO) is a high order finite-difference method, based on structured grids, designed for shock capturing. It has been widely used in applications for high-resolution supersonic flow simulations, typically the cosmological hydrodynamic involving both shocks and complicated smooth solution structures. Consider the system of hyperbolic conservation laws, 3D Euler equation for the fluid without any viscous:

\[ \frac{\partial U}{\partial t} + \frac{\partial F(U)}{\partial x} = 0 \]

Where \( U \) is the state variable, \( F(U) \) is the flux function, \( t \) is the time, \( x \) is the spatial coordinate.

The weak scaling of 128³ per process

Results

Speedup of 128³ WENO scheme on single GPU
- C2070 with Fermi architecture
- K20m with Kepler architecture

• 340.26 ± 28.75 iterations for 1,000,000,000 steps
• The strong scaling of 256²*256*128

Future work

1. We can reduce the data-copy time by porting all the computations related to the data in WENO computations to GPU. We can hide the MPI-communication time by overlapping it with the computing time. The ghost data can be updated on a different thread in a different block and corresponds to the processing of a group of all points along X-axis. The parallel strategy for WENO scheme is the same but along the different axis directions.

2. We can develop a hybrid algorithm that both CPU and GPU take part in computing simultaneously. In some supercomputers (Titan, Tianhe-1A), one node is equipped with a lot of CPU cores but only one GPU. It is important that how to distribute computational task between CPU and GPU for good load balancing.