Accelerating LSST Source Catalog Simulations with Graphics Processing Units

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The use of graphics processing units (GPUs) for computationally intensive tasks has gained a significant amount of traction in the field of high performance computing. For highly parallelizable applications, GPUs provide a factor of 20-100 increase in speed over conventional CPUs which could dramatically improve the performance of the LSST data management and simulation systems. Here, we present the results of porting a source catalog simulation code (gafast) to NVIDIA GPUs that resulted in typical speedups of 25-100x over the prior CPU-based code. Gafast is a generator of realistic mock catalogs of astronomical sources (e.g., stars in the Galaxy), originally written to interpret SDSS observations. Within LSST, gafast stellar catalogs are used as inputs to image simulations (ImSim), as well as by several Science Collaborations to estimate LSST yields of various astrophysical objects. It is available as a web service at http://hybrid.mwscience.org. The inner routines of gafast were modified to run on NVIDIA GPUs (~3000 lines of CUDA C code, four weeks of porting time). The effort resulted in typical speedups of order 100x (single Tesla S1070 GPU vs. a single contemporary CPU core). The time to generate simulated catalogs of Milky Way stars decreased from days to under an hour, becoming entirely bound by disk data transfer time. In a extreme example, a catalog computation that used to take 7 hrs was reduced to 0.3-0.5 seconds. While algorithmic changes are partially responsible for the speedup, we conservatively estimate that at least a factor of 25 speedup came from the use of GPUs. The success of this effort vividly demonstrates the ability of GPUs to bring significant speedup to LSST modeling and science. Work is ongoing to bring GPU-based acceleration to LSST ImSim code.

LSST: Observing and Measuring 10G Stars and Galaxies

The LSST will cover about 30,000 deg² with 5σ=3.5σ, imaged multiple times in six bands (ugrizy), with zenith 5σ for point sources of r=0.47. About 96% of the observing time will be devoted to a fast deep-sky survey mode which will observe a 20,000 deg² region and yield a coadded map up to r=21.1. These data will result in databases including 10 billion galaxies and a similar number of stars. An empirically constrained simulation of this dataset, the “source catalog”, should be used as the basis for LSST planning image simulations. Science Book estimates, data management, as well as operations simulations. However, the generation of this dataset proved difficult; for example, using existing tools the generation of stellar source catalogs would take on order of weeks per realization.

By using Graphics Processing Units (GPUs) as math accelerators, we were able to speed up this process by typical factors of >100. This enables the efficient generation of multiple source catalogs, and the full exploration of allowable model parameter space. Ultimately, the same code will be used in the dynamical modes of the Milky Way to actual survey data, thus providing a direct scientific as well as operational benefit.

Graphics Processing Units (GPUs) as mass accelerators:

- Massively Multi-Core Architecture
- Hundreds of simple cores (ALUs)
- Minimal program control logic – run the same program on different data
- Explicit memory hierarchy (GPU texture)
- Zero-overhead thread context switching
- 100x more computational power
- 90% of GPU transistors are devoted to math
- Fast basic math (single precision, FP4x slower)
- Hardware implementation of common functions (sin, cos, exp, log, ...

GPU Computing: Massively Multi-core Scientific Computing

GPU Implementation of Gafast

- Gafast: The Fast, Scalable, Synthetic Stellar Catalog Generator
- Generates ~3000 lines of CUDA C code
- C/C++ interface
- Output format:
  - Scalar and vectorized output
  - CSV format
- Benchmarks and Results

References

- Cosic et al., 2007, AJ, 134, 2398
- Bond et al., arXiv:0609.0013