GPUs and Einstein's Equations

Tim Dewey
tdewey@math.umd.edu
AMSC Scientific Computing
Advisor: Dr. Manuel Tiglio
tiglio@umd.edu
Physics Department and CSCAMM

Laser Interferometer Gravitational-Wave Observatory (LIGO)

Problem Introduction

- LIGO is depending on reliable simulations to identify black hole detections in very noisy data.
- Black hole simulations are computationally intensive.
- GPUs are a reasonably flexible and efficient for large scale computations.
- Using GPUs may reduce computation time and cost.
- This project will focus on building up code that will be the groundwork for simulating black holes on GPUs.

Project Summary

- Implement a spectral method PDE solver to solve Einstein's equations.
  - Prototype a spectral solver in Matlab.
  - Port this code to C for a single CPU.
  - Port computationally intensive C code to CUDA for a single GPU.
  - Port entire spectral solver to CUDA (function call from host CPU).
- Optimize RHS computation for Einstein's equations.

Implementation Challenges

- Designing the code to handle a large number of equations and potentially more than one dimension in space.
- Small memory on the GPU; hence the use of spectral methods.
- CPU host and GPU communication.
  - If only part of the algorithm is implemented on GPU, each time step requires CPU/GPU communication.
  - Ideally, CPU calls GPU function, GPU returns with a solution after all time steps are complete.

Validation/Databases (Known solutions)

- Various functions can be compared to known answers (e.g., derivative approximations can be compared to trivial functions with known analytic solutions).
- The full solution to Einstein's equations will be compared to the analytic solution of a spherically symmetric black hole.

Performance Testing

- It is not clear how to compare CPU performance and GPU performance.
- We will collect data on the time it takes to compute solutions for various problem sizes on both the GPU and CPU, but this will not immediately suggest one is better than the other.
- We will provide data that will help people make an informed decision about whether to use GPUs or CPUs for their problem.

Project Schedule

12/1	Matlab code verified on test data.
12/1	Written plan for C code.
2/10	C code verified on test data.
2/15	Outline for CUDA code.
3/15	CUDA verified on test data.
4/15	Optimized 1-d CUDA code.
5/1	Complete write-up of results.

Deliverables

- Matlab, C, and CUDA code to solve Einstein's equations.
- Complete code documentation.
- Write-up explaining results of code performance testing.

Questions?