Using CUDA for GPUs with MPI to solve Nonlinear Evolution Equations

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Introduction
Nonlinear evolution equations model important physical phenomena such as water waves (equation 1, below) and optical fiber communication systems (eq. 2).

1: Korteweg-de Vries equation (KdV)¹
\[ u_t + 6uu_x + u_{xxx} = 0 \]

2: Nonlinear Schrödinger equation (NLS)²
\[ iu_t = u_{xx} + 2|u|^2u \]

The goal of the work is to accelerate the computation of these equations using a network of GPU-enabled hosts communicating via Message Passing Interface (MPI).

Approach
Developing methods for solving the nonlinear evolution equations KdV and NLS on multiple GPUs communicating over MPI. The work will focus on three major components to create a solution:

1. Discovering fine-grained data parallelism in the problems and using CUDA (Compute Unified Device Architecture) to accelerate those calculations on the GPUs
2. Using Nvidia’s CUFFT (CUDA Fast-Fourier Transform) library to compute the Fourier transform of the linear part of modeled equations
3. Using MPI over CUDA to distribute the problem across multiple GPUs

Discussion
The speedups observed in the initial tests demonstrate significant gains in performance with even the most naïve implementation. Computationally similar linear algebra operations will be adapted to solve banded systems that are needed in solving equations 1 and 2. With further research, there is potential for greater performance gains through optimization and distribution over multiple GPUs.

Contributions
- Modeling water waves
- Modeling optical fiber communication systems
- Applications in physics, chemistry, and biology

References

Acknowledgments
I would like to acknowledge my major professor, Dr. Thiab Taha, for his invaluable support, and the Nvidia corporation for their donation of equipment.