18.337 Midterm/Final Project Proposal

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October 12, 2016

1 Finite Element Modeling in Julia

A major thrust of my research is centered around the development of Hybridizable Discontinuous Galerkin schemes to solve the incompressible Navier-Stokes equations. Discontinuous Galerkin schemes offer many opportunities for parallel implementation, since many of the computations are performed on each element independent of other elements. This is especially true of the HDG methodology, in which the computational bottleneck is the assembly and solution of a very large linear system using element-local data, making at least the assembly of the system embarassingly parallel. Right now, codes developed to implement these schemes have mostly been serial codes written in Python. I would like to re-write a large portion of these codes in Julia in order to take advantage of Julia's speed / good abstraction / lack of overhead compared to Python. I do so with the goal of conducting high resolution simulations of ocean flows.

2 Methodology

1. Implementation of parallel algorithms for finite element operator assembly
2. Benchmarking and comparison to serial codes performing the same operator assembly
3. Investigation of a matrix-based vs. matrix-free solve of the global linear system
4. It is possible that the matrix-free iterative solve algorithm can be parallelized as well
5. Benchmarking and comparison of the two solve methodologies, and possibly a comparison of the serial / parallel algorithm performance given the size of the system.
6. Implementation of parallel solution reconstruction and post-processing algorithms in an element-local manner
7. Investigation of the feasibility of multi-core vs. GPU programming for parallelization

This represents a significant amount of work for me, and I wish to combine the midterm and final projects.

3 Application

Along with the benchmarking, I would ideally like to use these improvements to run some ocean simulations demonstrating internal wave behavior under the presence of tides. Such information is difficult to capture without a high degree of freedom count, to the point of a simulation taking a week or more to run. The goal is that the faster codes and parallel algorithms, I will be able to capture these dynamics with shorter runs.