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Navier–Stokes solver for GPUs

Proposal for a master thesis

Introduction

This thesis is concerned with a direction splitting algorithm for the solution of the *time-dependent incompressible Navier–Stokes equations* [1, 2]. The idea behind the algorithm is to replace the standard Poisson problem for the pressure correction by a series of one-dimensional second-order boundary value problems.

$$A\,p(\boldsymbol{x}) = (1-\partial_{xx})(1-\partial_{yy})(1-\partial_{zz})pp(\boldsymbol{x}) = q(\boldsymbol{x}), \qquad \boldsymbol{x} = (x, y, z).$$

The direction splitting algorithm has been announced in [3]. Its performance has been analyzed in [1] where it is shown that solving with A is more efficient than solving with the Laplacian Δ. Only tridiagonal systems have to be solved instead of executing Fast Fourier transforms (FFTs).

The purpose of this work is to port the direction splitting algorithm to the GPU. The algorithm is provided as a compact MPI-parallelized FORTRAN 90 code.

Numerical tests will concern the start-up flow in a three-dimensional impulsively started lid-driven cavity of aspect ratio $1 \times 1 \times 2$ at Reynolds numbers 1000 and 5000 using grids consisting of up to $2 \cdot 10^9$ nodes.

Description of the task

The direction splitting algorithm is provided as a FORTRAN 90 code. This code is parallelized for distributed memory machines by means of MPI (Message Passing Interface). The code is to be analyzed. The MPI tasks are to parallelized for graphics boards (GPUs) with CUDA. Target machines with have *multiple* GPUs.

Requirements

- Good knowledge in FORTRAN, CUDA, and parallel computing.
- Good knowledge of numerics is useful.

Deliverables

- The work is to be documented in a short and concise thesis (LaTeX, PDF). It must be written such that it is intelligible to a fellow-student.
- The code should be written as clean as possible. It must be properly documented.
- At the end of the thesis, the work is to be presented in a 30 minutes' talk.

Contact

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References

[1] J.-L. Guermond and P. D. Minev. A new class of massively parallel direction splitting for the incompressible Navier–Stokes equations. *Comput. Methods Appl. Mech. Engrg.*, 200(23-24):2083–2093, 2011.

[2] J.-L. Guermond and P. D. Minev. Start-up flow in a three-dimensional lid-driven cavity by means of a massively parallel direction splitting algorithm. *Int. J. Numer. Methods Fluids*, 68:856–871, 2012.

[3] J.-L. Guermond and A. Salgado. A splitting method for incompressible flows with variable density based on a pressure Poisson equation. *J. Comput. Phys.*, 228(8):2834–2846, 2009.

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