Jingchang Shi

Personal information

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University	Northwestern Polytechnical University	Specialty	Ph. D. in CFD
		Job objective	HPC

Education

Sep 2014 - Dec 2021	**Ph. D. Computational Fluid Dynamics**, Northwestern Polytechnical University
Oct 2016 - Sep 2018	**Visiting Ph. D. Student (CFD)**(sponsored by CSC), University of Kansas, US
Sep 2010 - Jun 2014	**Bachelor in Aeroengine**, Northwestern Polytechnical University

Massively parallel CFD code

I develop a massively parallel CFD code NFS based on the high order Flux Reconstruction (FR) scheme. With Fortran 2008, it is organized in the OOP way. Similar to the famous open source code OpenFOAM, NFS is a general CFD solver on the unstructured grid. It has been verified in lots of cases and is able to solve various cases with the user provided input file and grid.

Highlights of NFS include the following

- Algorithm breakthrough: Overcome the intrinsic shortcoming of the high order FR scheme to extend it to the shock/turbulence boundary layer interaction (STBLI) case.
  - It is **the 1st code in the literature of the world** using the FR and related schemes to accurately capture the low-frequency flow separation in the STBLI case.
  - To successfully simulate the hard case of STBLI requires sophisticated collaborations of multiple state-of-the-art CFD algorithms, which is achieved in NFS.
- Good scalability: **The strong scalability test on the TianHe-2 shows 90% of ideal speed-up up to 2400 cores.**
- Good HPC performance: **Vectorization + template generated kernel function results in multiple times faster** running speed than the baseline.
- Good Multigrid performance: The baseline implicit time solver is the Block LU-SGS solver, which splits the full matrix A of the fully implicit time scheme into smaller matrix and calls LU decomposition from MKL to solve $Ax = b$. It alleviates the burden of huge memory storage for the full matrix A but retains the good speed-up. Based on the BLUSGS solver, the V-cycle Multigrid achieves multiple times faster running speed.

Profession skills

1. Proficient in C++, Fortran, Python
    - Use C++ in developing the hpMusic code during the visit to a famous CFD figure Z.J. Wang's group
    - Use Fortran in developing the NFS code which is part of the National Numerical Wind tunnel project
    - Use Python to post-processing the simulation data and build the prototype of a new algorithm
2. Proficient in HPC environment and MPI
    - MPI is used as the parallel programming model in NFS to communicate data among nodes on HPC
        - Use the user defined MPI indexed data type to pack all the communication data and it results in only one send-recv operation in each step.
        - The non-blocking MPI communications enable the overlap of the computation and the communication.
        - With the above MPI tricks, **the strong scalability test on the TianHe-2 shows 90% of ideal speed-up up to 2400 cores.**
    - Experiences in CFD code optimizations on HPC
        - Optimal design of data structure of CFD algorithm to help the compiler do vectorization
        - Use Python template engine jinja2 to generate Fortran kernel function to reduce the instructions retired in CPU
        - With the above tricks, the running speed of NFS reaches 3 times faster than the baseline
        - Run parallel CFD simulations using NFS with more than 1M CPU core-hours on BSCC and TianHe-2.
3. During the undergraduate stage, I used CUDA to implement a Poisson equation solver and employed multiple core CUDA optimization tricks including coalesced memory access, reduced threads divergence and redirected data access to shared memory to obtain a good performance.

Publications

1. J. Shi, H. Yan, Z.J. Wang, Flux reconstruction implementation of an algebraic wall model for large-eddy simulation, AIAA Journal. 58 (2020) 3051–3062. https://doi.org/10.2514/1.j058957.
2. J. Shi, H. Yan, Z.J. Wang, Towards direct computation of aeroacoustic noise with the high-order FR/CPR method, in: 2018 AIAA/CEAS Aeroacoustics Conference, AIAA, 2018. https://doi.org/10.2514/6.2018-4095.
3. J. Shi, H. Yan, Z.J. Wang, An algebraic wall-model for large eddy simulation with the FR/CPR method, in: 2018 AIAA Aerospace Sciences Meeting, AIAA, 2018. https://doi.org/10.2514/6.2018-2092.
4. J. Shi, H. Yan, G. Bai, K. Lin, Effect of thermal actuator on vortex characteristics in supersonic shear layer, in: 47th AIAA Fluid Dynamics Conference, AIAA, 2017. https://doi.org/10.2514/6.2017-4307.
5. J. Shi, H. Yan, Effects of thermal actuators on turbulent structures and acoustics of mach 1.3 jet, in: 2015 Chinese Congress of Theoretical and Applied Mechnics, Chinese Society of Theoretical and Applied Mechanics, 2015.
6. M. Mortazavi, D.D. Knight, O.A. Azarova, J. Shi, H. Yan, Numerical simulation of energy deposition in a supersonic flow past a hemisphere, in: 52nd Aerospace Sciences Meeting, AIAA, 2014. https://doi.org/10.2514/6.2014-0944.
7. J. Shi, H. Yan, CUDA implementation of a laplace solver, in: 2013 Chinese Congress of Theoretical and

Applied Mechnics, Chinese Society of Theoretical and Applied Mechanics, 2013.

Prizes

- Ph. D. 1st class and 2nd class scholarship of Northwestern Polytechnical University
- Distinguished graduate of Northwestern Polytechnical University
- Merit student of Northwestern Polytechnical University
- 1st class scholarship of Northwestern Polytechnical University
- “Wu Yanjun” scholarship of Northwestern Polytechnical University
- “7081” scholarship of Northwestern Polytechnical University
- National 2nd prize in Contemporary Undergraduate Mathematical Contest in Modeling
- National 3rd prize in National Undergradute Energy Saving Competition

Research projects

1. Study of STBLI using the high order FR scheme
    - CFD algorithm breakthrough: Create **the 1st code in the world** which successfully employs the high order Flux Reconstruction scheme to simulate the hard case of STBLI with the help of multiple state-of-the-art algorithms.
    - HPC optimization: Exploit vectorization in each grid cell and template generated kernel function to assist the compiler optimization, along with the non-blocking MPI communications and user defined packed data type to reduce the MPI communication costs
    - Mixing precision: Use quad-precision floating number to ensure the accuracy of FEM metrics but use double precision floating number to do simulation.
2. Systematic study of wall-modeled LES in the framework of FR
    - Clarify the misunderstanding of the wall-parallel grid requirement for the wall-modeled LES to work
    - **Propose the analytic solution to an ODE model of the wall model.** Previous literature calls an ODE solver in each time step. With the new analytic solution, polynomial evaluation directly gives the answer and it is 7 times faster than the MKL ODE solver.
3. Through the cases of a generic car mirror and the 30P30N three element airfoil, the high-order FR/CPR method is accurate and efficient in predicting the near-field aero-acoustics associated with turbulent vortices.
4. Demonstrate that the thermal actuators are able to effectively control round jets.
