Aircraft Noise Simulations (CABARET) Get Faster and Reach Bigger Models with HECToR dCSE Optimisations

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HPC experts from NAG, working under NAG's Computational Science and Engineering (CSE) support service for HECToR, the UK's national academic supercomputing facility, have implemented substantially better performance in the CABARET code, enabling the investigation of problems at least 100 times larger than previously possible.

The CABARET (Compact Accurate Boundary Adjusting high REsolution Technique) code may be used to solve the compressible Navier-Stokes equations, and in the context of this project, for the investigation of aircraft noise. An important component of aircraft noise is due to airframe/engine installation effects, the reduction of this remains a very challenging problem. In particular, when deployed at a large angle of attack at approach conditions, the wing flaps become a very important noise source. For engine-under-a-wing configurations, flap interaction with the jet can even become a dominant noise component. A crucial element of any noise prediction scheme is the high fidelity Large Eddy simulation (LES) model. For the airframe/engine noise problem, this model needs to accurately capture all important wing-flap, free jet and wing-flap-jet interaction effects.

Commenting on the dCSE project success, Sergey Karabasov (the Principal Investigator) said "*The dCSE project has been very useful in several respects. The acceleration provided by empowering the general-purpose LES CABARET code with HPC capabilities on HECToR allows us to use a significantly higher resolution than was previously possible on local small-size clusters.*"

HECToR

HECToR is managed by EPSRC on behalf of the participating Research Councils with a mission to support capability science and engineering in UK academia. The Cray XT supercomputers, located at the University of Edinburgh, are managed by UoE HPCx Ltd. The CSE Support Service is provided by NAG Ltd and ensures researchers have access to appropriate HPC expertise to effectively exploit advanced supercomputers. A critical feature of the CSE Support Service is the distributed CSE (dCSE) programme which, through lightweight peer review, delivers dedicated performance and scalability projects on specific codes in response to proposals from users. The dCSE programme now consists of over 50 projects complementing the traditional HPC user applications support and training provided by NAG.

The dCSE projects completed so far have delivered outstanding examples of the cost savings and new science that can be enabled through dedicated CSE effort. The CABARET project reported here adds to these success stories with a successful performance improvement.

Project Background

This goal of this dCSE project was to develop a distributed parallel version of the compressible CABARET code. This included the an efficient method of parallel partitioning in relation to the CABARET stencil and Fluent (Gambit) unstructured hexahedral mesh, modification of the CABARET code to include MPI data passing protocols between cell faces and cell centres and implement a simplistic method of post-processing for visualisation.

Sergey Karabasov of the University of Cambridge was the Principal Investigator on the project. Phil Ridley of NAG carried out the 10 person-month project in collaboration with the NAG CSE team and the CABARET developers. Over 25 million AUs (allocation units) are planned for use on HECToR to run CABARET simulations.

Project Results

An automated geometrical domain decomposition method for partitioning a Gambit generated unstructured grid was developed. The facility to use ParMetis or PT-Scotch is available for future geometries, as structured partitioning ensures better load balancing. An MPI parallel version of CABARET was implemented using non-blocking MPI to pass data between cell faces and sides. The newly developed code was validated and tested against the serial code and a parallel efficiency of 72% was observed when using 250 cores of the XT4 part of HECToR with the quad core Phase 2a architecture. Due to the introduction of the many-core architecture of Phase 2b, it was necessary to include the development of a hybrid (OpenMP/MPI) parallel version of CABARET for Phase 2b and furthermore a hybrid parallel partitioner. With the hybrid CABARET code, for the 3D backward-facing step test case of 51.2M cells, a parallel efficiency of 80% is achieved on 1000 cores of Phase 2b.

Simulations can now be performed on grids at least 512 times larger than previously possible. For smaller grid scales, time averaged, high Reynolds number (Re) simulations can now be performed in a few hours rather than several days. The general-purpose large eddy simulation CABARET code together with the HPC capabilities of HECToR allows the PI and extended group to use a significantly higher resolution than was previously possible on local clusters.

A full technical report can be found at http://www.hector.ac.uk/cse/distributedcse/reports/

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