Post doc : High Performance Solver for simulation of 3D hypersonic flows on Petascale supercomputers

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Description of the Cluster of excellence CPU

The Cluster of excellence CPU brings together teams belonging to 6 research laboratories in Bordeaux. This cluster is expected to have a long-term structuring role in both the academic and economic spheres through the production and transfer of cutting-edge knowledge in numerical and digital technologies.

Numerical and digital technologies are omnipresent in our everyday life and their use in the scientific and industrial worlds are constantly evolving. Numerical computations were first used as a tool to explain complex phenomena for which explicit computations or direct experiments were not possible. The next stage was the use of scientific computing as a dimensioning and designing tool in some industrial sectors.

CPU researchers will focus their energy on three main research areas heading to important breakthroughs in several high reliability demanding application domains (Health, Fluids, Aeronautics and telecom, Land transportation and Energy). The aim of this project is easy to state: we want to develop numerical sciences at such a level that it can be used as a certification tool.

For more information: http://cpu.labex-univ-bordeaux.fr/en/

Duration 18 months

Job statuts Post doc

LOCATION Inria

DATE September 2014

Description

This proposal for a postdoctoral position is a joint proposal from Inria and CEA in the scientific context of High Performance Computing for reentry problems.

The purpose of the HiePACS project-team (https://team.inria.fr/hiepacs/) is to perform efficiently frontier simulations arising from challenging research and industrial multiscale applications. HiePACS intends to contribute to all steps that go from the design of new high-performance more scalable, robust and more accurate numerical schemes to the optimized implementations of the associated algorithms and codes on very high performance supercomputers (extreme scale computing).

The French Alternative Energies and Atomic Energy Commission (CEA) is developing numerical methods devoted to the numerical simulation of three-dimensional hypersonic flows problems. This type of flows is encountered during the atmospheric re-entry of space vehicles and is characterized by extreme physical conditions (very high Mach number, very strong bow shock and very important thermal fluxes at the boundary of the space vehicle). Here, we are interested in optimizing and adapt the computational performances of an existing three-dimensional Navier-Stokes code on large supercomputers (composed by more than one hundred thousand cores). A multiblock structured strategy is employed to decompose the computational flow field domain around the configuration subject. Steady state solutions are obtained from a time marching algorithm that solves the unsteady compressible Navier-Stokes equations. The inviscid fluxes are evaluated by means of a Roe type approximate Riemann solver and the second-order extension with respect to the space discretization employs the classical Harten-Yee approach. The time stepping procedure relies on an implicit time discretization of the Navier-Stokes equations which allows to perform the time marching algorithm with reasonnably high values of time steps. After linearizing the non-linear discrete Navier-Stokes equations with respect to the current time step, one gets a large linear system to solve which is

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characterized by a sparse non symmetric matrix with real valued entries. Different kinds of classical solvers are employed such as Jacobi and Gauss-Seidel ones. Recently, the Navier-Stokes solver has been linked to the PETSc library (developed by Argonne National Laboratory). The current methodology to solve linear systems within the present Navier-Stokes solver relies either on a domain decomposition followed by a non-preconditionned Gmres solver or on a global preconditionned parallelized Gmres solver.

In this proposal, we aim at solving challenging 3D problems characterized by a billion of cells with a number of degrees of freedom ranging from 7 to 20. As explained before, these problems will be run on hundreds of thousands of cores of large-scale supercomputers. The candidate will have access to leading edge computational platforms as well as prototypes of experimental systems available at Inria and CEA.

The candidate will start by analyzing and optimizing the computing performances of the Navier-Stokes solver in his actual configuration on large-scale supercomputers for the aforementioned challenging problems. Then, following this preliminary analysis and according to the results obtained, the candidate may explore two new strategies.

The first one consists in rewriting the linear system solver to propose an alternative methodology which relies on a progressive refinement of the computational zones with a partial overlapping of these zones. This amounts to develop a hierarchical overset Chimera strategy which might be compatible with large deformation of the computational grids.
The second one aims at investigating and revisiting the capability of the algebraic multigrid methods to solve highly compressible Navier-Stokes equations. These two strategies, in the present context, should permit to provide computing performances and a very good scalability, well adapt to the future large-scale supercomputers.

Profile of applicant

PhD degree in computer science, computational science, applied mathematics or a related scientific application domain area such as fluid mechanics is required. Excellent written and oral communication skills and a good experience with code development in a UNIX/Linux-base environment are required too.

Desired experience in one ore more of the following areas :

I. High-Performance Computing (Parallel Linear Algebra);
II. Domain science expertise relevant to fluid mechanics;
III. Experience for tuning and debugging large science applications.

Supervisors/Contact

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Application deadline :