ONERA

THE FRENCH AEROSPACE LAB

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POST-DOCTORATE PROPOSAL

Title : Improving the performance of the industrial numerical flow solver CODA on extreme-scale parallel computing systems

Reference : **PDOC-DAAA-2021 -08**
(to be recalled in all correspondence)

Start of contract: As soon as possible	**Application deadline:** 15 November 2021

Duration: 12 months, possibly extendable to 24 months - Net yearly salary: about 25 k€ (medical insurance included)

Keywords

parallel programming, code optimization techniques, HPC, Computational Fluid Dynamics, CFD

Profile and skills required

Minimum qualifications:

- A PhD in computer science, applied mathematics or a closely related topic
- Proficient in programming and working with C/C++, Python, Linux
- Familiar with parallel programming models (MPI and OpenMP) and code optimization techniques
- A keen interest in performance analysis, profiling tools, and computing architectures
- Good level of spoken and written English

Additional qualifications:

- Previous experience with large simulation software (for industrial or research applications)
- Knowledge of collaborative tools such as Git, GitLab, Gerrit or similar
- Background in Computational Fluid Dynamics, Finite Volume or Discontinuous Galerkin methods
- Background in linear algebra and in particular sparse iterative solvers

Presentation of the post-doctoral project, context and objective

Since 2017, ONERA has been developing in collaboration with AIRBUS and DLR (German Aerospace Center) a new common software, named CODA, for the simulation of flows for complex industrial applications. The CODA solver includes classic finite volume capabilities and novel high-order discontinuous Galerkin schemes, all specifically tailored for aeronautical applications, and will be the reference solver for aerodynamics applications inside the AIRBUS group including Civil transport aircraft and Helicopters.

In order to be able to treat different and varied complex applications with competitive turnaround times, the CODA solver is implemented as a highly modularized and flexible C++17 library with a python user interface. Template metaprogramming is extensively used to provide high flexibility with generic programming while ensuring high runtime performance and reducing to a minimum runtime polymorphism. Both distributed and shared parallelism are employed by using MPI and OpenMP in order to obtain high-parallel efficiency on modern HPC architectures and the possibility of exploiting GPUs is currently under study. Finally in order to optimize the collaborative work of more than 40 active developers, modern software developing practices are extensively used, which include the use of best coding and formatting practices, distributed version control and continuous integration practices with automated testing, code analysis and benchmarking.

The fundamental objective of the proposed research activity is to increase the performance of CODA solver for large scale simulations. Some optimization axes will be investigated and several proofs of concept developed before any implementation into the solver. Specific attention will be paid to the capabilities of the existing multilevel parallelism and the efficiency of the current partitioning mesh strategies.These activities take place in the framework of the European NextSIM project (2021-2024) (nextsimproject.eu). The selected candidate will therefore interact with all partners of the CODA and NextSIM projects (which additionally include Cerfacs, Barcelona Supercomputing Center, CIMNE and the University of Madrid).

The research activities to be conducted are:

- Evaluate serial and parallel performance of the CODA solver. Numerical experiments will be carried out for different applications and on different HPC architectures to draw out bottlenecks. Daily interactions with developers involved in topics such as discretization schemes or high-performance computing will help to draw first conclusions.
- Analyse the suitability of commonly used data-structures. Identify opportunities of efficiency improvements and do proofs of concept by developing external devoted prototypes. This study will require a detailed analysis of the dominant kernels of the CODA solver and will ask for a particular knowledge of target HPC architectures specificities that could be acquired via other NextSim partners.
- Contribute to activities related to load balancing of parallel computations over the course of the different phases of simulations. Performance models will be developed to ensure the mesh partitioning strategy will lead to satisfactory levels of load balance. The possibility of performing dynamic load balance, i.e. redistributing the computational mesh during the simulation, will also be considered. Such studies will necessarily take into account technical and implementation details of high-order discretizations or linear solvers depending on the target applications.
- Interact with all partners involved in the development of CODA and take benefit from previous experiences gained from other ONERA solvers.

External collaborations

CODA Project : Airbus and DLR

NextSIM European Project: Cerfacs, Barcelona Supercomputing Center, CIMNE, University of Madrid

Host laboratory at ONERA

Department : Aerodynamics, Aeroelasticity, Acoustics

Location (ONERA centre): Chatillon

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