A propos du centre ou de la direction fonctionnelle

An important force which has continued to drive HPC has been to focus on frontier milestones which consist in technical goals that symbolize the next stage of progress in the field. After the step of the teraflop machine in the 1990s, the HPC community envision the use of generalist petaflop supercomputers and soon coming exaflop machines in the 2020s. For applications codes to sustain petaflop and more using a few millions of cores or more will be needed, regardless of processor technology. Currently, a few HPC simulation codes easily scale to this regime and major code development efforts are critical to achieve the potential of these new systems. Scaling to at this rate will involve improving physical models, mathematical modelling, super scalable algorithms that will require paying particular attention to acquisition, management and visualization of huge amounts of scientific data.

In this context, the purpose of the HiePACS project is to perform efficiently frontier simulations arising from challenging research and industrial multiscale applications. The solution of these challenging problems require a multidisciplinary approach involving applied mathematics, computational and computer sciences. In applied mathematics, it essentially involves advanced numerical schemes. In computational science, it involves massively parallel computing and the design of highly scalable algorithms and codes to be executed on future petaflop (and beyond) platforms. Through this approach, 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.

Contexte et atouts du poste

Wave propagation phenomena intervene in many different aspects of systems design at Airbus. They drive the level of acoustic vibrations that mechanical components have to sustain, a level that one may want to diminish for comfort reason (in the case of aircraft passengers, for instance) or for safety reason (to avoid damage in the case of a payload in a rocket fairing at take-off). Numerical simulations of these phenomena plays a central part in the upstream design phase of any such project. Airbus Central R&T has developed over the last decades an in-depth knowledge in the field of Boundary Element Method (BEM) for the simulation of wave propagation in homogeneous media and in frequency domain. To tackle heterogeneous media (such as the jet engine flows, in the case of acoustic simulation), these BEM approaches are coupled [3] with volumic finite elements (FEM). We end up with the need to solve large (several millions unknowns) linear systems of equations composed of a dense part (coming for the BEM domain) and a sparse part (coming from the FEM domain). Various parallel solution techniques are available today, mixing tools arising from the academic world (such as the Mumps [4, 5] and Pastix [6] sparse solvers) as well as parallel software tools developed in-house at Airbus (dense solver SPIDO, multipole solver [1], H-matrix solver [2] with an open-source sequential version available online [9]). In the current state of knowledge and technologies, these methods do not permit to tackle the simulation of aeroacoustics problems at the highest acoustic frequencies (between 5 and 20 kHz, upper limits of human audition) while considering the whole complexity of geometries and phenomena involved (higher acoustic frequency implies smaller mesh sizes that lead to larger unknowns number, a number that grows like $f^2$ for BEM and $f^3$ for FEM, where f is the studied frequency).


Mission confiée

In this research project, we are interested in many aspects that include the design of new advanced techniques to solve these large mixed dense/sparse linear systems, the extensive comparison of these new approaches to the existing ones, and the application of these innovative ideas on realistic industrial test cases.

- The use of H-matrix solvers on these problems will be investigated (in the continuation of a PhD currently in progress). Airbus CR&T, in collaboration with Inria Bordeaux Sud-Ouest, has developed a task-based H-matrix solver on top of the runtime engine StarPU [7]. The question of parallel scalability of task-based tools is an active subject of research, using new communication engine such as NewMadeleine [8], that will be investigated during this project, in conjunction with new algorithmic ideas on the task-based writing of H-matrix algorithms.

- Ideas coming from the field of sparse direct solvers (such as nested dissection or symbolic factorization) have been tested within H-matrices. This activity will be continued and extended.

- Comparison with existing tools will be performed on large realistic test cases. Coupling schemes between these tools and the hierarchical methods used in H-matrix will be developed and bench as well.


Principales activités

Different possibilities exist as main subjects of research in this framework (to be discussed with the candidates):

- Implementation of a new approach to handle larger blocks in a task-based H-matrix solver. One of the challenge in solving this kind of problems is the ability to scale efficiently when both the matrix size and machine size increase. The current way of dealing with large H-matrix blocks is a limitation in this regard, so a new way will be implemented, and all the H-matrix task based algorithms will be adapted to this novelty.

- Solve a coupled FEM-BEM (sparse/dense) linear system using one unique H-matrix. The current approach in Airbus software is to solve a 2x2 linear system, storing 4 separate matrices (FEM-FEM, FEM-BEM, BEM-FEM and BEM-BEM). If we choose to use the same H-matrix solver for both sparse and dense matrices, one can consider storing all the system in one unique matrix with an adapted shape and ordering.

- Evaluate different scheme of partitioning and ordering for solving sparse linear systems with H-matrices. The nested dissection and the H-matrix have both introduced ways of partitioning the unknowns adapted to their respective fields. Solving sparse systems with H-matrix allows to test both
approaches and all the intermediate steps between the two.

- Exhaustive performance measure and modelisation of existing solvers for FEM/BEM solver. Several different solvers exist to tackle the linear system considered, not to mention the one we propose to develop in this study. We want to measure, analyze and understand the advantages and drawbacks of each methods regarding memory footprint, accuracy, performance, scalability, etc.

In each possible subjects, all the steps for a study will be taken care of : theoretical and bibliographic research, prototyping, implementation, tests, validation, results analysis, report. All these points will be dealt with during the PhD, if time permits. Moreover, this list is not static, other ideas may appear or replace existing topics.

Compétences
Technical skills and level required :

- Knowledge in the fields of linear algebra and finite element methods;
- Programming skills in C/C++ and script language;
- Knowledge in distributed and shared memory parallelism (MPI, threads);
- Ability to design and conduct a numerical experiment plan.

Languages : English required

Avantages
Subsidized meals
- Partial reimbursement of public transport costs
- Possibility of teleworking (after 6 months of employment) and flexible organization of working hours
- Professional equipment available (videoconferencing, loan of computer equipment, etc.)
- Social, cultural and sports events and activities
- Access to vocational training
- Social security coverage

Rémunération
- 1982€ / month (before taxes) during the first 2 years
- 2085€ / month (before taxes) during the third year