2018-00417 - Post-doctoral - Parallel Mesh Adaptation: refinement and load balancing

Level of qualifications required: PhD or equivalent
Function: Post-Doctoral Research Visit

About the research centre or Inria department

The goal of the TADaaM project is to design and build a stateful system-wide service layer for HPC systems. This layer will be twofold. First, it will abstract low-level features of the system (e.g. topology, network, resource usage) and of the software stack (e.g. threads, data, runtime system). Second, applications will be able to register their needs and behaviors thanks to a carefully designed API. With these two sets of information, the layer will optimize the execution of all the running applications in a coordinated fashion and at system-scale.

Context

INRIA scientific priorities: Bridging time and space scales

Scientific context:

Among High Performance Computing (HPC) applications, simulation based on finite element method features unstructured meshes that discretize and model the simulated objects. In case of very large problems, this mesh is partitioned into domains that are distributed across the processing units, so as to be processed in parallel. However, during the course of the simulation, it may happen that it is required to refine some part of the mesh (to increase the accuracy of the simulation of the corresponding domain) or on the contrary to coarsen some part of the mesh. This step is called remeshing. As the compute time of each domain depends on their number of elements, the remeshing often implies a huge imbalance in terms of computation between the different processing units. Such imbalance generates a waste of resource usage and a strong loss of performance. To avoid this problem, it is necessary to repartition and redistribute the mesh among the processing units during the remeshing step.

The PaMPA [1] library [2] (for “Parallel Mesh Partitioning and Adaptation”), whose development started within the Bacchus (now Cardamom) team [3], aims at abstracting mesh handling operations on distributed memory environments. It relieves solver writers from the tedious and error-prone task of writing service routines for mesh handling, data ordering, communication and exchange, remeshing, and data redistribution. Its repartitioning features are based on the PT-Scotch [2] library [5, 6], while its parallel remeshing features rely on third-party sequential remeshers such as the MMG3D [3] library developed within the Cardamom team. PaMPA written in C and uses MPI for communication.

The AeroSol [4] library has been developed since 2011 within the teams Bacchus (now Cardamom) and Cagire. This library aims at handling continuous and discontinuous finite element methods on hybrid and possibly curvilinear meshes, and at being able to run on heterogeneous architectures. It uses PaMPA all aspects related to mesh management.

[1] https://project.inria.fr/pampa/

Assignment

The goal of this postdoc is to work on the remeshing phase of PaMPA, in the case of very large load imbalance. Indeed, while PaMPA is able to repartition meshes in parallel, it incurs heavy run-time penalties because of load imbalance, in cases when some area has to be refined significantly. The goal of this postdoc is therefore to design and implement new
remeshing strategies for these cases.

Main activities

To achieve this goal, the work program is decomposed into the following steps:

- Implement a multicriteria parallel partitioning algorithm within PT-Scotch. The goal is to compute a partitioning of the mesh that minimizes inter-domain communication as well as the imbalance. Such work will be based on the results of Rémi Barat [1] and Sébastien Morais [4] PhD theses at CEA.
- Calibrate the above algorithm by carefully determining the needs in terms of remeshing as well as the impact of the different parameters on the performance.
- Provide a performance model of the MMG3Dto evaluate the time and memory required to refine or coarsen a given submesh.
- Based on the above model, schedule the different remeshing tasks in parallel onto the available resources.
- Adapt the existing data movement features of PaMPAthis newly designed strategy.

This work will be tested using real use cases implemented within the AeroSol. Depending on the advance of the project, other use cases arising from a collaboration with the CERFACS (AVBP: LES simulation for combustion) will be studied. The work will be carried out in collaboration with the CardamomCagire, who develop AeroSol.

Keywords: Mesh, High-Performance Computing, MPI, load balancing, finite element method

References:

[1] Rémi Barat. Load balancing of multiphysics simulations by multi-criteria graph partitioning. Theses, Université de Bordeaux, December 2017


Skills

Required knowledge and background:

The candidate must have a PhD. related to HPC, meshes, domain decomposition and graph partitioning. Strong C programming skills are required. The candidate must also be knowledgeable in MPI and able to implement its solution into a large, existing software. Basic knowledge in numerical simulation (CFD, finite element method, etc.) would be a plus.

Benefits package

- Subsidised catering service
- Partially-reimbursed public transport

Remuneration

2653€ / month (before taxes)
General Information

- **Theme/Domain**: Distributed and High Performance Computing
- **Town/city**: Talence
- **Inria Center**: CRI Bordeaux - Sud-Ouest
- **Starting date**: 11/1/18
- **Duration of contract**: 1 year, 4 months
- **Deadline to apply**: 4/19/18

Contacts

- **Inria Team**: TADAAM
- **Recruiter**: Pellegrini Francois / francois.pellegrini@inria.fr

Conditions for application

Thank you to send:

- 4 pages CV
- Cover letter
- At least 2 support letters (mandatory)
- List of publication
- PDF of the most relevant publication
- Defense report
- Reviewer thesis report

Defence Security:
This position is likely to be situated in a restricted area (ZRR), as defined in Decree No. 2011-1425 relating to the protection of national scientific and technical potential (PPST). Authorisation to enter an area is granted by the director of the unit, following a favourable Ministerial decision, as defined in the decree of 3 July 2012 relating to the PPST. An unfavourable Ministerial decision in respect of a position situated in a ZRR would result in the cancellation of the appointment.

Recruitment Policy:
As part of its diversity policy, all Inria positions are accessible to people with disabilities.

**Warning**: you must enter your e-mail address in order to save your application to Inria. Applications must be submitted online on the Inria website. Processing of applications sent from other channels is not guaranteed.