Offer #2025-08549

PhD Position F/M Foundation of an HPC Composition Model

Contract type : Fixed-term contract

Level of qualifications required : Graduate degree or equivalent

Fonction : PhD Position

About the research centre or Inria department

The Inria research centre in Lyon is the 9th Inria research centre, formally created in January 2022. It brings together approximately 320 people in 19 research teams and research support services.

Its staff are distributed in Villeurbanne, Lyon Gerland, and Saint-Etienne.

The Lyon centre is active in the fields of software, distributed and high-performance computing, embedded systems, quantum computing and privacy in the digital world, but also in digital health and computational biology.

Context

Numerical simulation is a key technology for many application domains. Thanks to the democratization of high performance computers (HPC), complex physics and more generally complex systems can now be simulated routinely. Numerical simulation is considered as the third pillar of sciences (with experiment and theory) and is critical to gain competitive position.

Though significant efforts have been devoted to the implementation and optimization of several crucial parts of a typical HPC software stack, most HPC experts agree that exascale supercomputers will raise new challenges, mostly because the trend in exascale compute-node hardware is toward heterogeneity and scalability: Compute nodes of future systems will have a combination of regular CPUs and accelerators (typically GPUs), along with a diversity of GPU architectures.

Meeting the needs of complex parallel applications and the requirements of exascale architectures raises numerous challenges which are still left unaddressed. As a result, several parts of the software stack must evolve to better support these architectures. More importantly, the links between these parts must be strengthened to form a coherent, tightly integrated software suite.

The **Exa-SofT** project of the PEPR **NumPEx** aims at consolidating the exascale software ecosystem by providing a coherent, exascale-ready software stack featuring breakthrough research advances enabled by multidisciplinary collaborations between researchers.

Assignment

The particular issue that this PhD shall tackle is to provide a model to composose code develop accordingly to various HPC programming paradigms. Software composition is an old [NATO] but still key technique [SZY] to develop complex applications by being able to divde them into manageable code. Though it is common in traditionnal sequential programming, composition parallel codes is still challenging. Previous work demonstrated that composition within a parallel programming is possible and do not impact performance [CCA, HLCM, Comet]. However, we are lacking a model to compose distinct paradigms without mentioning the specific problem of runtime cohabitation in an HPC context.

A particular target of this work could be the Multi-Level Intermediate Representation (MLIR) framework [MLIR], aiming to harness MLIR not only as a unifying compilation target for heterogeneous input Domain Specific Languages (DSLs) but also as a semantic backbone for expressing data flow, and reasoning about scheduling.

Bibliography:

- [NATO] Mcllroy, M.D., Mass Produced Software Components. Proceedings of NATO Software Engineering Conference, Garmisch, Germany, October 1968, 138-155.
- [SZY] Clemens Szyperski. Component Software : Beyond Object-Oriented Programming. Addison-Wesley Longman Publishing Co., Inc., 2002.
- [CCA] B. A. Allan, R. Armstrong, D. E. Bernholdt, and al. A component architecture for high-performance scientific computing. International Journal of High PerformanceComputing Applications, 20(2) :163–202, 2006.
- [HLCM] Julien Bigot. Du support générique d’opérateurs de composition dans les modèles de composants logiciels, application au calcul scientifique. PhD thesis, INSA de Rennes (France), 2010.
- [COMET] Jérôme Richard. Conception d’un modèle de composants logiciels avec ordonnancement de tâches pour les architectures parallèles multi-coeurs, application au code Gysela. PhD Thesis, Université de Lyon, December 2017.
- [MLIR] C. Lattner *et al.*, "MLIR: Scaling Compiler Infrastructure for Domain Specific Computation," *2021 IEEE/ACM International Symposium on Code Generation and Optimization (CGO)*, Seoul, Korea (South), 2021, pp. 2-14, doi: 10.1109/CGO51591.2021.9370308.

Main activities

- Study the state-of-the-art of parallel paradigms, parallel programming models, and composition models
- Analyse challenges for incomming parallel applications
- Propose a model that supports composition of of selected programming principles
- Implement a proof of concept (POC)
- Conduct evaluation of POC on selected use cases

Skills

Technical skills and level required :

- knowledge of HPC programming models
- knowledge in (meta-)modeling will be appreciated
- very good programming skills (in particular in C++ but not only)

Benefits package

- Subsidized meals
- Partial reimbursement of public transport costs
- Leave: 7 weeks of annual leave + 10 extra days off due to RTT (statutory reduction in working hours) + possibility of exceptional leave (sick children, moving home, etc.)
- Possibility of teleworking (90 days / year) and flexible organization of working hours Social, cultural and sports events and activities
- Access to vocational training
- Social security coverage under conditions

Remuneration

1st and 2nd year: 2100 euros gross salary /month

3rd year: 2200 euros gross salary / month

General Information

- **Theme/Domain :** Distributed and High Performance Computing Software engineering (BAP E)
- **Town/city :** Lyon
- **Inria Center :** Centre Inria de Lyon
- **Starting date :** 2025-09-01
- **Duration of contract :** 3 years
- **Deadline to apply :** 2025-08-02

Contacts

- **Inria Team :** AVALON

- **PhD Supervisor :**
  Perez Christian / christian.perez@inria.fr

About Inria

Inria is the French national research institute dedicated to digital science and technology. It employs 2,600 people. Its 200 agile project teams, generally run jointly with academic partners, include more than 3,500 scientists and engineers working to meet the challenges of digital technology, often at the interface with other disciplines. The Institute also employs numerous talents in over forty different professions. 900 research support staff contribute to the preparation and development of scientific and entrepreneurial projects that have a worldwide impact.

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.

Instruction to apply

Applications must be submitted online via the Inria website. Processing of applications submitted via other channels is not guaranteed.

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.