Offer #2024-07156

PhD Position F/M PhD in Exascale parallel optimization using Fractal-based decomposition

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 University of Lille centre, created in 2008, employs 360 people including 305 scientists in 15 research teams. Recognised for its strong involvement in the socio-economic development of the Hauts-De-France region, the Inria University of Lille centre pursues a close relationship with large companies and SMEs. By promoting synergies between researchers and industrialists, Inria participates in the transfer of skills and expertise in digital technologies and provides access to the best European and international research for the benefit of innovation and companies, particularly in the region.For more than 10 years, the Inria University of Lille centre has been located at the heart of Lille's university and scientific ecosystem, as well as at the heart of Frenchtech, with a technology showroom based on Avenue de Bretagne in Lille, on the EuraTechnologies site of economic excellence dedicated to information and communication technologies (ICT).

Context

This PhD will be carried out in the framework of the PEPR (Programme et Equipement Prioritaire de Recherche) NumPEx[1] project devoted to Exascale Optimization for the Exascale and financed by the France2030 investment program.

Assignment

Location: INRIA Lille

Duration: 3 years

Application: Candidates must have a master in computer science or other relevant

fields. Good programming skills are required. Applications should be sent to

el-ghazali.Talbi@univ-lille.fr

They should include:

- a curriculum vitae;
- a motivation letter;
- at least two referees with their e-mail addresses;

Hosting research team: BONUS INRIA team: Solving BOPs (Big Optimization Problems) raises at least four major challenges: (1) tackling their high dimensionality; (2) handling many objectives; (3) dealing with computationally expensive objective functions; and (4) scaling on (ultra-scale) modern supercomputers. The overall scientific objectives of the Bonus project consist in addressing efficiently these challenges. On the one hand, the focus will be put on the design, analysis and implementation of optimization algorithms scalable to high-dimensional (in decision variables and/or objectives) and/or expensive problems. On the other hand, the focus will also be put on the design of optimization algorithms able to scale on heterogeneous supercomputers including several millions of processing cores. To achieve these objectives raising the associated challenges a program including three lines of research will be adopted: *decomposition-based optimization, Machine Learning (ML)-assisted optimization and ultra-scale optimization*.

Main activities

Context

On one hand, in many scientific and industrial areas we are witnessing the emergence of **big optimization problems (BOPs)** which refer to problems characterised by:

- *Large number of decision variables and data parameters* it will induce high-dimensionality in the problems. For instance, in smart grids, there are many BOPs for which it has to be considered a large number of consumers (e.g. appliances, electrical vehicles) and multiple suppliers.
- *Mixed variables*: many BOPs involve continuous, discrete and categorical variables. In the automated design of deep neural networks, the new architectures could be composed of billions of mixed variables: continuous (e.g. weights), discrete (e.g. number of layers) and categorical (e.g. type of layer).
- *Expensive objective functions*: optimization problems often involve time-consuming objective functions. In many BOPs, the objective functions consist in the execution of expensive simulations of a black-box complex system (e.g. multi-disciplinary engineering design).
- *Multiple objective functions*: indeed, optimization problems encountered in practice are rarely single-objective. In general, there are many conflicting objectives to handle; for instance, minimising the cost, maximising the performance and minimising the environment impact of a system.

Combining ultra-scale fractal decomposition and chaotic optimization for BOPs is the first break-through of this project. The main challenges are: (i) the design of chaotic global search procedures to explore the fractal space; (ii) the design of chaotic local search procedures to intensify the search in deep fractals; (iii) and the extension of chaotic search to solve multi-objective and mixed optimization problems.

On the other hand, **high-performance computing (HPC)** technologies have known a revolution in the last decade. HPC is evolving toward supercomputers composed of millions of cores provided by heterogeneous devices mainly multi-core CPUs with GPU accelerators. We entered the exascale *era* since June 2022, as the Top500 revealed the USA Frontier machine to be the first exascale supercomputer. The EU, China and Japan all have next-generation exascale projects. The EU's ambition is to become one of the world leaders in supercomputing. France is preparing a response to EuroHPC's next call to host the exascale European machines planned for the 2024 deadline.

Research directions

Inspired by nature-inspired complex systems, my main concern in this project is to "think" high-dimensional, massively parallel, and heterogeneous. The three innovative and complementary objectives of the project for solving BOPs in an effective and efficient way are:

- Design of ultra-scale fractal decomposition algorithms. Ultra-scale algorithms refer to algorithms generating an unprecedented and unlimited amount of independent sub-problems in parallel.
- Design of chaotic optimization algorithms for an effective and efficient search in fractal spaces.
- Heterogeneous design and implementation on Exascale supercomputers including millions of CPU and GPU cores, and billions of spiking neurons of neuromorphic architectures.

Validation and application

There is a plenty of new big optimization problems in science and industry. The proposed methodology will be validated on three complementary families of BOPs with a great environmental, societal and economic impact, and different needs in terms performance/energy trade-off. In this PhD, we will focus on the automated design of **deep neural networks.** Deep neural networks (DNNs), such as convolution neural networks (CNNs) and Vision Transformers (ViTs), are successful in solving various hard AI problems such as computer vision and natural language processing. DNNs are based on deep neural networks that could be giant including many layers of different types, billions of mixed variables and expensive learning [7].

References

[1] B. Mandelbroot, "The fractal geometry of nature",*W. H. Freeman and Company*, 1983.

[2] A. Tsonis, "Chaos: from theory to applications",*Springer*, 2012.

[3] E-G. Talbi, "Metaheuristics: from design to implementation", *Wiley*, 2009.

[4] A. Di Ieva (Ed.), "The fractal geometry of the brain", Springer, 2016.

[5] H-O. Peitgen, H. Jurgens, D. Saupe, "Chaos and fractals – new frontiers of science",*Springer*, 2004.

[6] J. Michael, T. Thompson, "Chaos, fractals and their applications",*Int. Journal on Bifurcation and Chaos*, Vol.26, No.13, pp.1-22, 2016.

[7] E-G. Talbi, "Automated design of deep neural networks: a survey and unified taxonomy", *ACM Computing Surveys*, Vol.54, No.2, 2021.

[8] T. Skordas, "Toward a European Exascale ecosystem: The EuroHPC joint

undertaking". *Communications of the ACM*, Vol.62, No.2, 2019.

[9] D. Schuman et al. "Opportunities for neuromorphic computing algorithms and applications."*Nature Computational Science, Vol.2, No.1, 2022*

[10] E-G. Talbi, "Machine learning into metaheuristics", *ACM Computing Surveys*, Vol.54, No.6, 2022.

Skills

Technical skills and level required : computer science, parallel computing.

Languages : english

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 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

Remuneration

Gross salary per month :

- 2,100€ the first and second year
- 2,190€ for the third year

General Information

- **Theme/Domain :** Optimization, machine learning and statistical methods
  Scientific computing (BAP E)
- **Town/city :** Lille
- **Inria Center :** Centre Inria de l'Université de Lille
- **Starting date :** 2024-10-01
- **Duration of contract :** 3 years
- **Deadline to apply :** 2024-05-31

Contacts

- **Inria Team :** BONUS
- **PhD Supervisor :**
  Talbi El-ghazali / El-Ghazali.Talbi@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

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.