Internship: **Exascale optimization using Fractal-based decomposition**

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This internship 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.

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.

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, the main concern in this project is to "think" high-dimensional, massively parallel, and heterogeneous. The three innovative and complementary objectives of the internship 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.

1 http://numpex.fr

- Heterogeneous design and implementation on Exascale supercomputers including millions of CPU and GPU cores.

Validation and application

The proposed methodology will be validated on generic continuous optimization problems and on the automated design of **neuromorphic neural networks.**

Location: INRIA Lille
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;
- links to PhD thesis and publications;
- links to software contributions.

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*.

References

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