2018-00447 - [Campagne Post-Doctorant 2018/CRI LILLE] - Hybrid optimization algorithms for ultra-scale supercomputers (M/F)

Type de contrat : CDD de la fonction publique
Niveau de diplôme exigé : Thèse ou équivalent
Fonction : Post-Doctorant

A propos du centre ou de la direction fonctionnelle

The Inria Lille - Nord Europe Research Centre was founded in 2008 and employs a staff of 360, including 300 scientists working in sixteen research teams. Recognised for its outstanding contribution the socio-economic development of the Nord - Pas-de-Calais Region, the Inria Lille - Nord Europe Research Centre undertakes research in the field of computer science in collaboration with a range of academic, institutional and industrial partners.

The strategy of the Centre is to develop an internationally renowned centre of excellence with a significant impact on the City of Lille and its surrounding area. It works to achieve this by pursuing a range of ambitious research projects in such fields of computer science as the intelligence of data and adaptive software systems. Building on the synergies between research and industry, Inria is a major contributor to skills and technology transfer in the field of computer science.

Contexte et atouts du poste

Job environnements

Branch-and-Bound (B&B) methods are tree-based algorithms allowing to solve optimization problems to optimality at the price of time-intensive exploration. Conversely, metaheuristics are approximate optimization methods having nice parallelization properties allowing the generation of high-quality solutions in relatively short computing times. In the literature [1], many reported experiments demonstrate that the best results are obtained through hybridization combining exact algorithms and metaheuristics. In addition, parallel computing is highly required to support the overhead induced by this later mechanism.

The focus of this proposal is put on the design and implementation of parallel hybrid optimization algorithms combining B&B and metaheuristics for solving very hard permutation-based problem instances on modern supercomputing. According to the Top500 international ranking [2], these later include up to millions of processing cores provided in various resources including multi-core processors having different architectures, GPU accelerators and coprocessors such as Xeon Phi. These properties (large scale in cores and heterogeneous resources) providing different levels of parallelism make it difficult to exploit all the performance delivered by such supercomputers. The challenge is therefore the design and implementation of hybrid optimization algorithms to solve efficiently large permutation problems. Such challenge is often partially addressed in the literature (GPU-accelerated metaheuristics, multi-core metaheuristics, ...) but, to the best of our knowledge, never in a holistic way targeting all the provided levels of parallelism.

The topic addressed in this proposal, a step on the road to the exascale era, is a major part of the research roadmap of the newly created BONUS (Big Optimization and Ultra-Scale computing) team. Moreover, it is related to the "High-performance computing and optimization" axis of the CPER "data" (2015-2020).

Mission confiée

Assignments

Nowadays, combinatorial optimization problems become increasingly large in terms of environmental parameters, decision variables and/or objective functions. To deal efficiently with such large scale, different scientific challenges must be addressed at algorithmic level as well as at mapping-to-hardware level.

Indeed, at algorithmic level efficient data structures are required to efficiently store and manage the “tsunami” of subproblems (e.g. a pool of $10^{14}$ for the 50-20 instances of the Flow-Shop scheduling Problem - FSP - potentially generated during the exploration process. For instance, in [3] we have proposed an original data structure called IVM, composed of an Integer, a Vector and a Matrix, for permutation problems.
Extensive experiments have revealed that IVM is highly efficient in terms of memory footprint and pool management for serial as well as parallel B&B exact algorithms [4]. On the other hand, the IVM-based B&B algorithm has been revisited for GPU-accelerated clusters using the Work Stealing paradigm. The experimentation of this algorithm on the GPU-enhanced IDRIS/UESSANT cluster using 130.000 GPU cores allowed to solve the Ta056 (50 jobs, 20 machines) difficult FSP instance within 9 hours.

The resolution time on a single CPU core is estimated to 22 years. However, even if parallel GPU-accelerated cluster IVM-based B&B allowed to solve a difficult instance of FSP with a high efficiency some preliminary experiments demonstrated that it fails when it comes to solve harder instances (e.g. Ta051). Therefore, the hybridization of B&B with (meta)heuristics [1, 6, 7, …] is necessary. The objective is not only to solve harder instances to optimality when it is possible but to improve the best known near-optimal solutions for these later ones otherwise.

On the other hand, parallel computing has recently undergone a significant evolution in terms of performance and energy saving with the emergence of multi- and many-core computing technologies (GPU, MIC, etc.) (see Top500 [2]). Indeed, accelerators and coprocessors have powered many parallel and/or distributed environments ranging from high-performance workstations to modern supercomputers (mainly large hybrid clusters) among them the top-ranked Top500/Green500 ones. Typically, a modern supercomputer supplies two major coarse levels of parallelism: intra-node and inter-node (or cluster-level). The intra-node level is tending to be heterogeneous (typically CPU+GPU) providing a hierarchy of CPU-side and GPU-side levels of parallelism. Recently, intra-node heterogeneous parallelism for optimization algorithms has been the focus of many research works [5]. However, most of these later do not exploit all the supplied levels of parallelism. In addition, to the best of our knowledge the combination of the intra- and inter-node levels is never addressed within the context of combinatorial optimization. Therefore, although existing parallel hybrid optimization algorithms allow to significantly reduce the size of the search space and speed up its exploration they often fail when it comes to tackle very large optimization problems.

The focus of this proposal is put on the design and implementation of parallel hybrid optimization algorithms (B&B + metaheuristics) for modern ultra-scale (massively parallel and heterogeneous) supercomputers. Raising such challenge requires to address several issues at two levels: combinatorial optimization and ultra-scale parallelization. At the optimization level, the major issue is to find how metaheuristics (ex. greedy algorithms) can help to guide B&B to find good solutions in an efficient way. From parallelization point of view, the objective is to extend the IVM-based ultra-scale B&B with the selected metaheuristics considering the various hybridization schema. Different parallel models of metaheuristics (parallel evaluation of a population, parallel exploration of a neighborhood, …) will be investigated on GPU-accelerated clusters with the objective to efficiently exploit the exposed hierarchical parallelism: cluster-level, multi-core level, GPU-level, core-level (vectorization).

From implementation point of view, we have already developed innovative approaches for parallel optimization on multi-core processors and GPU accelerators using MPI, OpenMP/Pthreads, Cuda or their combination. However, such programming approach is no longer sufficient with the advent of exascale era announced for 2022 [8]. On the path to exascale, the aim is to investigate the programming environments and execution support able to deal with exascale challenges: large number of threads, heterogeneous resources, etc. Various exascale programming approaches are being investigated by the parallel computing community and HPC builders: extending existing programming languages (e.g. DLS-C++) and environments/libraries (MPI, OpenMP, StarPU, etc.), proposing new solutions including mainly PGAS-based environments (Chapel, UPC, X10, etc.).

Finally, the proposed parallel hybrid optimization algorithms will be extensively experimented. The experiments will be conducted on the new hybrid cluster of the Grid’5000 infrastructure at Lille, acquired in the context of the CPER “data” and on the European PRACE supercomputers such as Piz Daint (an application is already submitted to get access to this later supercomputer). For validation, different optimization problems will be considered including FSP, TSP, QAP, etc.

Bibliography


**Principales activités**

Main activities:

- State of the art on hybrid optimization (B&B + metaheuristics)
- Design and implementation of some hybridization schema
- Parallelization for large-scale heterogeneous supercomputers
- Experimentation on some permutation problems (Flow-Shop, QAP, ...) using Grid'5000 and Prace-level supercomputers
- Publications in high-ranked journals

**Compétences**

Skills

Combinatorial Optimization, Metaheuristics, Parallel Computing, Programming (C++/Python, parallel programming libraries).

**Avantages sociaux**

- Subsidised catering service
- Partially-reimbursed public transport
- Social security
- Paid leave
- Sports facilities
- Flexible working hours

More information about Lille:

http://www.lille3000.eu/portail/

http://www.lillemetropole.fr/mel.html

**Remunération**

Remunerating

The gross monthly salary is 2653€