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Title of the proposal: Parallel Tree-based Exact Algorithms using Heterogeneous Many and Multi-core Computing for Solving Challenging Problems in Combinatorial Optimization

Keywords: GPU and Multi-core Computing, Combinatorial Optimization, Tree-based Exact Methods, Permutation Problems

Many research works have been carried out on parallel strategies for solving large-scale combinatorial optimization problems using tree-based exact algorithms such as branch-and-bound (B&B) algorithms [1]. Different parallel environments have been targeted: MPP machines, networks and clusters of workstations, and SMP machines. Recently, we have successfully revisited parallel B&B algorithms for computational grids [2]. The proposed approach allowed the resolution of the Ta056 instance of the Flow-Shop problem within 25 days using over 2000 processors from Grid5000. The resolution time of such instance on a single machine is 22 years! (second Award in Grid’5000 Spring School, Grenoble 2006).

Recently, GPU accelerators and multi-core processors have emerged as a new powerful support for massively parallel computing. Their combination is particularly challenging for the design and implementation of efficient algorithms. In combinatorial optimization, GPU computing has been successfully used for parallel meta-heuristics (near-optimal combinatorial optimization), for instance in our works [3, 4, 5] (nominated for the Best Paper Award in Evocop’2010). However, to the best of our knowledge, no contribution has been proposed for tree-based exact optimization algorithms neither on GPU nor on multi-core machines.

The objective of this proposal is the design and implementation of parallel tree-based exact algorithms on heterogeneous clusters including multi-core processors as well as GPU accelerators. The focus will be on Branch-and-X (X = Bound, Cut or Price) algorithms for permutation-based problems (QAP and QA3P, TSP, Flow-Shop, …). In [2], we have proposed an original approach for parallel B&B on computational grids. The challenge in this proposal is to re-think the design of the algorithm taking into account its own characteristics and those of heterogeneous many and multi-core clusters. In other words, how to efficiently explore a large irregular tree on such clusters? Several issues have to be dealt with: tree partitioning and data transfer between the multi-core processors and their
associated GPUs, synchronization, memory management of the GPUs, global information sharing, dynamic load balancing, fault tolerance, hybrid programming (task and data parallelism, shared-memory and message-passing paradigms, etc.).

From implementation point of view, the designed algorithms will be implemented following framework-oriented. The developed software framework will allow the programmer to reuse the design as well as the code of the algorithms to solve any permutation-based optimization problem. For its validation, experimentations will be carried out on some challenging instances (“success stories”) of permutation problems such as QAP/Q3AP and Flow-Shop using the heterogeneous cluster of GRID5000 at Lille. The cluster includes 20 bi-processors quad-core i.e. 160 processor cores + 8 bi-processors quad-core, each processor is coupled with 4 GPU Fermi with 448 cores each.

**Bibliography:**


**Pre-requisites:**

To be eligible to apply for this project, the applicant must demonstrate knowledge and skills in parallel computing, and object-oriented programming (C++). Knowledge in GPU and multi-core computing, combinatorial optimization, exact algorithms is also desirable.