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A novel List-Constrained Randomized VND approach in GPU for the Traveling Thief Problem

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Abstract

The Traveling Thief Problem (TTP) is a multi-component combinatorial optimization problem that combines two well-known problems in the literature: the Traveling Salesman Problem (TSP) and the Knapsack Problem (KP). This paper proposes a novel list-constrained local search process inspired in Variable Neighborhood Descent (VND) for multiple neighborhood structures, combined with a metaheuristic Greedy Randomized Adaptive Search Procedure (GRASP). The local search implementation was made in a Graphics Processing Unit (GPU) architecture in order to explore the massive number of computing cores to simultaneously explore neighbor solutions, while the GRASP was implemented exploring the natural parallelism of a multi-core CPU. The computational results were compared to state-of-the-art results in literature and indicate promising research directions for the design of novel search algorithms in high performance architectures.

Keywords: Traveling Thief Problem, Variable Neighborhood Descent, Graphics Processing Unit, GRASP, Local Search

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1 Introduction

In the real-world, problems usually tend to be related to each other and solving problems sub-parts separately may not solve the target problem itself. This is the case of several practical applications in the classic problems such as the 0/1 Knapsack Problem [10] and the Traveling Salesman Problem [5]. For the latter, a recently studied variant that computes the latency cost (or accumulated cost) has been tackled by a multi-neighborhood algorithm using a Graphics Processing Unit (GPU), inspired by Variable Neighborhood Search (VNS) metaheuristic [4] and the Variable Neighborhood Descent (VND) [12]. Many other variants of these classic problems can be found in literature, however few of them are successful in combining both problems in order to challenge existing state-of-the-art strategies for each problem separately.

In this paper we deal with the Traveling Thief Problem (TTP) [2], a combination of the Traveling Salesman Problem (TSP) and the 0/1 Knapsack Problem (KP), using both classic well known optimization problems. These two components have been merged in such a way that the optimal solutions for each problem do not necessarily correspond to an optimal TTP solution [14]. A practical application for the TTP is indicated by Mei et al. [8] and consists of a routing problem with service profit, where each costumer has a demand and a service profit, and the travel cost depends on the load of the vehicle. Another evidence for the importance of considering the impact of vehicle load in travel costs is related to carbon emissions and can be seen in the Green Vehicle Routing Problem literature [7]. By studying the TTP it is possible to perform a systematic investigation of interactions between two hard optimization problems, to eventually help solving real-word problems more efficiently [3].

We propose a novel List-Constrained Randomized VND (LCRVND), which is capable of simultaneously exploring multiple neighborhood structures in a heterogeneous CPU-GPU environment. The idea of using a GPU is that its many-core architecture is composed of thousands of processing cores that allow a massive number of operations to be processed virtually simultaneously, and as soon as an improving neighbor is found for the current solution, its neighborhood also starts to be explored. Obviously, if all possible neighborhoods are explored by the method it would perform a complete enumeration of the search space, which is costly and highly inefficient for search purposes.

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