A Parallel Bee Life Algorithm for DCVRP on GPUs

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1 Introduction

Capacitated Vehicle Routing Problem (CVRP) represents one of Vehicle Routing Problem (VRP) variants involving in different constraints which can be found various references such as in Toth and Vigo [1]. This problem is one of the most studied problems in combinatorial optimization domain, due to its important applications in areas of logistics and transportation. Initially, VRP was introduced by Dantzig and Ramser [2] as a generalization of Travelling Salesman Problem (TSP).

In CVRP, a fleet of homogeneous vehicles serves a set of customers starting from one depot and returning to it. This fleet is intended to provide all known customers' orders with a reduced cost, expressed by the total travelled distance. CVRP considers that all vehicles possess same and limited capacity of deliveries assigned to a number of clients.

The dynamic version of the Capacitated Vehicle Routing Problem abbreviated DCVRP is seen as a new class of VRP problems and considered as NP-hard problems [3]. DVRP has arisen as result of recent advances in information and communication technologies that allow new events such as new requests, happening even when customers are in stage to be served. So, DCVRP requires a dynamic and a real time update of its prior solution during its run time.

Finding the optimal solution in DCVRP requires very long computational CPU time due to its very high complexity. Consequently, advanced optimization methods (i.e. metaheuristics) have been applied as efficient approaches to solve this kind of problems with very low complexity [4, 5]. However, with very high DCVRP instances (i.e. the number of customers or the occurred new events or orders), the quality of the found solution using conventional metaheuristics can be improved by advanced computational approaches, namely the parallel processing.

In the literature, parallel optimization methods were used to solve some optimization problems such as in [4, 6, 7]. Moreover, the performance and effectiveness of special processors, such as General Purpose Graphics Processing Units (GPGPUs) for data parallel processing, are improving very rapidly. Today's CPUs equipped with GPUs are greatly efficient that traditional CPUs in terms of arithmetic throughput and memory bandwidth.

In this paper, we propose a new parallel metaheuristic on GPU called Parallel Bees Life Algorithm (P-BLA) to solve DCVRP problems in order to surmount complexity of conventional metaheuristics and to make computational time of routes dynamically found very acceptable. The parallelization of P-BLA can be achieved in a number of ways depending on data structure and available hardware used to solve DCVRP [8].

2 Parallel Bee Life Algorithm on GPU for DCVRP

We investigate the DCVRP models proposed by Montemanni et al. [9]. They considered a DCVRP as the extension to the standard CVRP by sub-dividing a working day into a number of discrete time periods, then the DCVRP can be formulated as a sequence of static instances, each one consisting of a conventional CVRP. New customer orders can continuously arrive overtime, even if a number of vehicles are starting the delivery process. These new orders need to be incorporated into the existing vehicle tours or new tours are created to handle with these new orders.

To solve DCVRP, two phases are proposed (fig. 1):

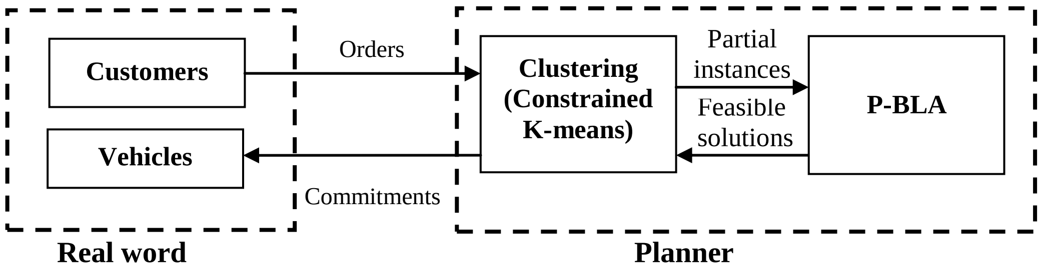
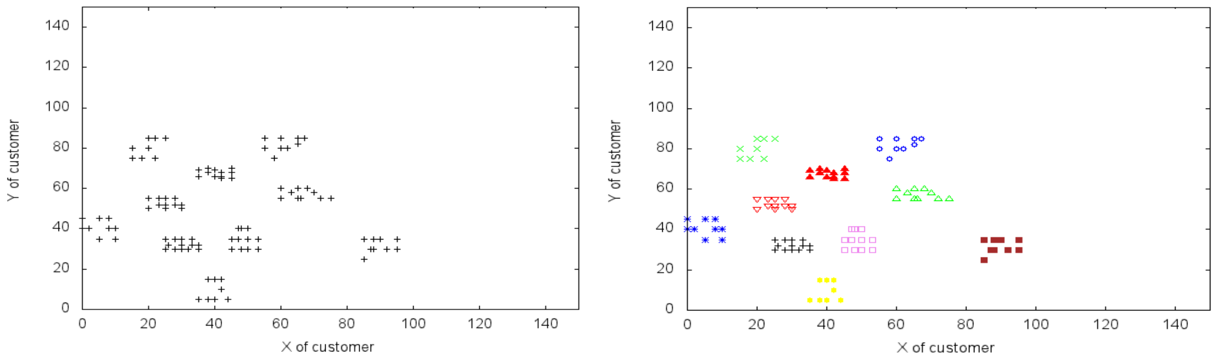


Fig. 1. Proposed solving model for DCVRP.

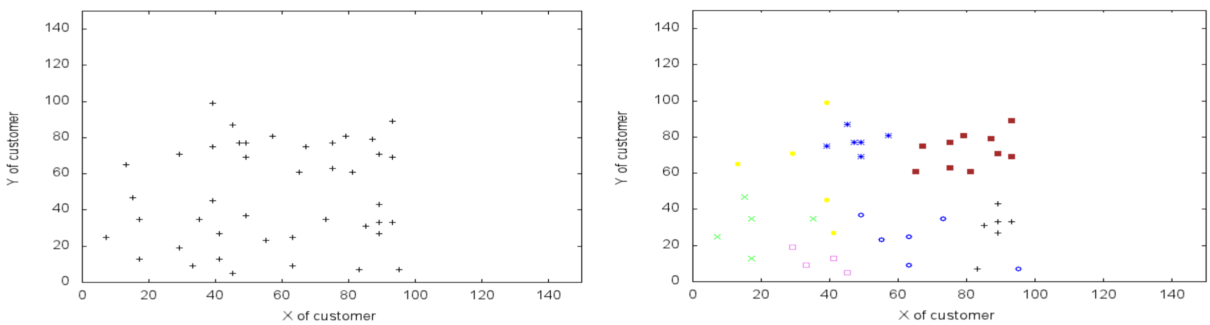
The first phase uses a constrained k-means method as a clustering phase of the initial CVRP configuration considered as the first configuration of our DCVRP, in order to design an efficient tool to deal with complex optimization data. This phase is proposed in order to divide the set of customers into *m* clusters according to *m* vehicles.

Each cluster must verify the capacity constraint of the vehicle, in which the total demands of consumers of each cluster should not exceed the capacity *Cmax* of a vehicle. The figures below (fig. 2 and fig. 3) illustrate the results reached of clustering with constrained k-means of some instances of CVRP benchmarks. Here, points with the same color describe the customers of the same cluster.



Before clustering After clustering

Fig 2. Instance name: Solomon 1- C101 (100 costumers, 10 vehicles).



Before clustering After clustering

Fig 3. Instance name: Augerat et al. A-n45-k7 (44 costumers, 7 vehicles).

In the second phase, the shortest path (in terms of minimum Euclidian distance) visited by each vehicle is computed in each cluster using a parallel Bee Life Algorithm (BLA) on the GPU. It is worth noting that BLA has been inspired by the two most important behaviors of bees in nature such as marriage and food source searching [10]. As a result, the optimal distances of several routes are reached as a global optimal solution of the DCVRP.

The most important languages that implement parallel algorithms on GPU architectures and development environments are OpenCL and CUDA [11, 12]. OpenCL is an open standard, whereas CUDA is a proprietary programming language proposed by NVIDIA Company. As perspective, we intend to implement P-BLA as the second phase, on CUDA in the aim to improve DCVRP results.

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