Enhancements to the Localized Genetic Algorithm for Large Scale Capacitated Vehicle Routing Problems

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ABSTRACT

This paper is a continuation of two previous papers where the authors used Genetic Algorithm with automated problem decomposition strategy for small scale capacitated vehicle routing problems (CVRP) and vehicle routing problem with time windows (VRPTW). In this paper they have extended their scheme to large scale capacitated vehicle routing problems by introducing selective search version of the automated problem decomposition strategy, a faster genotype to phenotype translation scheme, and various search reduction techniques. The authors have shown that genetic algorithm used with automated problem decomposition strategy outperforms the GAs applied on the problem as a whole not only in terms of solution quality but also in terms of computational time on the large scale problems.

Keywords: Automated Problem Decomposition Strategy, Capacitated Vehicle Routing Problem (CVRP), Contour Genotype to Phenotype Translation Scheme, Localized Genetic Algorithm (LGA), Localized Optimization Framework (LOF)

INTRODUCTION

The Vehicle Routing Problem (VRP) is an optimization problem that seeks to provide a solution to vehicle scheduling while minimizing (for example) cost or total travel times. As the problem is computationally intensive for problems of any realistic size, a sub-task is to find strategies to enhance the efficiency of the algorithm used to solve the VRP. One approach is to decompose the problem into smaller units, solve each one separately, and then recombine
them. In this context, the VRP can be said to represent the intersection of two combinatorial problems i.e., finding an optimal problem decomposition (Set Partitioning) and route optimization (Ordering). Please note that the two terms ‘problem decomposition’ and ‘set partitioning’ may have dissimilar meaning in other combinatorial problems. Some approaches optimize VRP as a whole without explicitly separating these two built in sub-tasks, while others perform decomposition then order the elements of the sub-problems independent of each other. Evidence has shown that the latter strategy is more successful. Work using genetic algorithms has mostly treated this problem as a whole. Although some applications of GA have treated these two sub-tasks separately, those applications used GA only for set partitioning and not for ordering. To our knowledge only one application of GA has appeared in the literature where the GA is used for optimization of customer ordering of sub-problems. However, it is a multi-depot problem (Surekha & Sumathi, 2011), where each sub-problem surrounds a single depot constituting a complete Capacitated Vehicle Routing Problem (CVRP). Apart from our earlier work (Ursani et al., 2009, 2011) no report has appeared in the literature where the GA is used for optimization of customer ordering of sub-problems. However, it is a multi-depot problem (Surekha & Sumathi, 2011), where each sub-problem surrounds a single depot constituting a complete Capacitated Vehicle Routing Problem (CVRP). Apart from our earlier work (Ursani et al., 2009, 2011) no report has appeared in the literature where the GA is used for optimization of customer ordering of sub-problems.

In the following subsections literature regarding the two sub-tasks of VRP i.e., (problem decomposition and ordering) is discussed separately. The ordering section deals with the problem representation of customer order and subsequent genotype to phenotype translation that has remained a core issue of GA in the area of VRP. In the context of VRP the term ‘order optimization’ is preferred to ‘route optimization.’

Problem Decomposition Strategies

Problem decomposition strategies have been in place for some time. They are also used for optimization of Vehicle Routing Problems. Some of those applications are discussed here. The first successful problem decomposition strategy applied to the VRP was a Tabu search (Rochat & Taillard, 1995). The problem was partitioned into sub-problems and then each sub-problem was optimized through the Tabu Search. The optimized sub-problems were joined together to form a global solution. This procedure was performed iteratively until good a quality solution was obtained. Different partition methods have been proposed for different types of datasets. The same method was extended by Gendreau, Hertz, and Laporte (1994) but ensured different partitions in each iteration. The GA has also been applied to the VRP with problem decomposition strategies but not for optimization of sub-problems. Instead, it has been used for the formation of sub-problems only, with those sub-problems subsequently being optimized through different approaches. One such application was introduced by Thangiah, Nygard, and Paul (1991). In this paper the GA was used to partition the dataset into sectors that were optimized through other heuristics. A similar approach was extended for school bus routing by Thangia and Nygard (1992) and again for VRPTW by Thangiah (1995). The approach was improved by incorporation of Tabu Search and Simulated Annealing by Thangiah (1999). Another adaptation for VRP with a multi-depot problem is presented by Thangiah and Salhi (2001). All the above work used a cluster first, route second approach where a GA was applied for clustering, sectoring or problem decomposition but not directly for route optimization itself. A very different problem decomposition strategy was adopted by Ralphs et al. (2003) where a CVRP problem was decomposed into a convex combination of Travelling Salesman Problem (TSP) tours that were later optimized through a parallel branch, cut, and price algorithm. An application of Ant Colony Optimization (ACO) with a problem decomposition strategy was used by Reimann, Doerner, and Hartl (2004), and called D-Ants i.e., Decomposed Ants. In this work the ACO was initially applied to the whole problem then
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