Efficient Heuristic for Large-Scale Vehicle Routing Problems Using Particle Swarm Optimization

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ABSTRACT
This paper addresses the Capacitated Vehicle Routing Problem (CVRP) with a homogenous fleet of vehicles serving a large customer base. The authors propose a multi-phase heuristic that clusters the nodes based on proximity, orients them along a route, and allots vehicles. For the final phase of determining the routes for each vehicle, they have developed a Particle Swarm Optimization (PSO) approach. Benchmark datasets as well as hypothetical datasets have been used for computational trials. The proposed heuristic is found to perform exceedingly well even for large problem instances, both in terms of quality of solutions and in terms of computational effort.

Keywords: Capacitated Vehicle Routing Problem (CVRP), Clustering, Discrete Particle Swarm Optimization (DPSO), Particle Swarm Optimization (PSO), Vehicle Routing Problem

1. INTRODUCTION
Globalization of industries and the boom in the market has resulted in a spurt in logistics. An important part of procurement and of distribution is the routing of vehicles such that the demands of the system are met at minimal costs. It is in this context, that the vehicle routing problem (VRP) has been chosen for the current study. The classical vehicle routing problem involves routing (Golden & Assad, 1988) a fleet of vehicles through several nodes such that every node is visited exactly once. The objective is to minimize the distance traveled. This in turn helps in reducing emission and minimizing the overall fuel consumption of the vehicles. The remainder of the paper is organized as follows: First we present a review of recent literature. After that contains a description of the solution methodology and then the results and discussions.

DOI: 10.4018/jgc.2012070103
2. LITERATURE REVIEW

A variety of approaches based on heuristics and meta-heuristics are reported for the Capacitated Vehicle Routing Problem and its variants. Bullnheimer et al. (1999) developed an improved Ant System algorithm for the VRP with one central depot and identical vehicles. Baker and Ayechew (2003) considered the application of a genetic algorithm (GA) to the basic vehicle routing problem (VRP), where customers, are served from a single depot. In this work, the vehicles were subject to a weight limit and the distance travelled. Berger and Barkaoui (2003) proposed a new genetic algorithm for the CVRP. A Simple and Effective Evolutionary Algorithm for the Vehicle Routing Problem was developed by Prins (2004). Osman et al. (2005) investigated the application of genetic algorithms to solve multi-objective routing problems. The proposed model eliminated the use of weight factor of each objective.

A new hybrid approximation algorithm based on discrete particle swarm optimization (DPSO) and simulated annealing (SA) was developed by Chen et al. (2006) to solve the CVRP. The algorithms combined global search and local search to search for the optimal results. Tavakkoli-Moghaddam et al. (2006) presented a linear integer model of CVRP with the independent route length to minimize the heterogeneous fleet cost and maximize the capacity utilization. The proposed model was solved by a hybrid simulated annealing (SA) based on the nearest neighborhood. A computational-efficient VRPTW algorithm, which was based on the principles of PSO, was developed by Z"{u}hu et al. (2006). Yu et al. (2008) proposed an Improved Ant Colony Optimization (IACO), which had a new strategy to solve the VRP.

Duhamel et al. (2009) addressed the Capacitated Location-Routing Problem (CLRP), raised by distribution networks involving depot location, fleet assignment and routing decisions. The proposed solution method was a greedy randomized adaptive search procedure (GRASP), calling an evolutionary local search (ELS). Pop et al. (2010) proposed an effective metaheuristic algorithm for a Generalized Vehicle Routing Problem (GVRP) based on genetic algorithms. The GVRP consisted of designing optimal delivery or collection routes, subject to capacity restrictions, from a given depot to a number of predefined, mutually exclusive and exhaustive node-sets. Marinaliskis et al. (2010) developed a hybrid PSO for the GVRP which combines a PSO algorithm, the multiple phase neighborhood search–greedy randomized adaptive search procedure (MPNS–GRASP) algorithm, the expanding neighborhood search (ENS) strategy and a path re-linking (PR) strategy.

Mendoza et al. (2010) extended multi-compartment vehicle routing problem (MC-VRP) by introducing uncertainty on what it is known as the MC-VRP with stochastic demands (MC-VRPSD). The algorithm was tested on instances of up to 484 customers using memetic algorithm. Duhamel et al. (2011) addressed an extension of the capacitated vehicle routing problem where customer demand is composed of two-dimensional weighted items (2L-CVRP). Aleman et al. defined a new constructive algorithm for the Split Delivery Vehicle Routing Problem (SDVRP) based on a novel concept called the route angle control measure and this approach was worked with an adaptive memory algorithm. Ngueveu et al. (2010) presented the first upper and lower bounding procedures for Cumulative Capacitated Vehicle Routing Problem (CCVRP) and developed an effective memetic algorithm for solving it. Lee et al. (2010) developed an enhanced ant colony optimization (EACO) is proposed for the CCVRP, which was based on both simulated annealing and ACO. So far in the literature, problems up to a size of 1000 have been addressed. In this paper, we address problems of larger sizes, going up to 2000 and seek quick and efficient solutions to such problems also.

3. PROBLEM DESCRIPTION

A fleet of \( V \) vehicles, each of capacity \( Q \), originating from a single, common depot must serve a set of \( N \) delivery nodes. Each node \( i \) is
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