Swarm and Evolutionary Computation 21 (2015) 41–53

Contents lists available at ScienceDirect

Swarm and Evolutionary Computation

journal homepage: www.elsevier.com/locate/swevo

Regular paper

The dynamic vehicle routing problem: Solution with hybrid metaheuristic approach

Jalel Euchi [a,*], Adnan Yassine [b], Habib Chabchoub [c]

[a] Laboratoire L.O.G.I.Q. – ISGIS, Université de Sfax, Route de Tunis, km 11 – B.P: 1164-3018, Sfax Tunisia
[b] Laboratoire LMAH – ISEL, Université du Havre, 25 rue Philippe LEBON, B.P. 540-76058, Le Havre Cedex France
[c] Institut des Hautes Etudes Commerciales de Sfax, University of Sfax, Route de Sidi Mansour km 10 – B.P. 1170-3018, Sfax Tunisia

ARTICLE INFO

Article history:
Received 28 December 2013
Received in revised form
23 November 2014
Accepted 29 December 2014
Available online 7 January 2015

Keywords:
Vehicle routing
Dynamic routing
Ant colony
2_Opt local search

ABSTRACT

The increased awareness in just-in-time supply systems with the apparition of the new advances in communication and information technologies, have recently led researchers to focus on dynamic vehicle routing problem (DVRP). In DVRP, client requests are not known and are exposed after making some decisions. An alternative variant dynamic pickup and delivery strategy of the vehicle routing problem arises when new customers appear in the tours after the starting visit. The DVRP are among the more important and more challenging extensions of VRP. The purpose of this paper is to propose an Artificial Ant Colony based on 2_Opt local search (AAC_2_Opt) to solve the DVRP. We demonstrate the effectiveness of our approach by comparing its results with those of existing methods in the literature on the same tests problems. The AAC_2_Opt algorithm can efficiently optimize the routing problem and provide highly competitive solution.

1. Introduction

Any organization involved in transport has to consider many types of problems. We have discussed some of the most important, but there are always operational details to consider as the number of vehicles needed, type and size, special features required, routes used, assignment of loads and customers to vehicles, schedules, maintenance schedules, measures of service and quality, and so on.

A basic routing problem looks for the best path for a delivery vehicle around a set of customers. There are many variations on this problem, all of which are notoriously difficult to solve. An important subtask in this context is the operational planning of trucks or other specialized transportation vehicles.

The high complexity and intractable nature of the DVRP forms an attractive row of research motivated by the significance of the transport industry. The transportation and logistics problems are optimized using a static model, but with the increasing of the traffic, and demand and with the flexibility of customers, the growing quantity of computing, and communication, the problem is studied in dynamic conditions.

There exist many models of the supply chain logistics systems, among them we consider the dynamic routing models which try to determine the optimal minimum total travel cost. The main characteristics of this type of problem are the uncertainty in the data and it can be due to different sources, and it can have different natures. The automaticity and flexibility are the main features and activities of the dynamic routing.

Here we will focuses on dynamic pick-up-and-delivery routing problem, i.e., where goods are collected from various customers and then delivered to a central depot. Each service request either has a combined pick-up and delivery location or only a single pickup (or delivery) location. The DVRP with pickup and delivery represents an interesting research issue since it presents some characteristic facial appearance with regards to the static pickup and delivery.

Due to recent advances in communication and information technologies the responsible of managing the planning of the transport have the possibility to resolve the problem in real time and we can obtain the solution quickly.

There are a few different approaches have employed to develop decisions support systems for the dynamic pickup and delivery VRP, but no exact algorithms have ever been presented to solve this variant. As we known, for large scale complex problems such as VRP, it is very difficult to develop exact methods to solve this type of problems. The majority of the existing studies deal with the metaheuristics.

The main goal of this study is to develop an Artificial Ant Colony based on 2_Opt local search algorithm to solve the dynamic pickup and delivery VRP. In the AAC meta-heuristic, a set of agents (ants) build solutions to the given problem cooperating through

* Corresponding author.

http://dx.doi.org/10.1016/j.swevo.2014.12.003
2210-6502/

pheromone-update. The success principles of AAC consist in an intelligent exploitation of the problem structure and in an effective interplay between the search space and the solution space elaborating with the local search.

Our main contribution in this paper is to introduce the DVRP with pickups and deliveries. It also provides an up-to-date survey of contributions to this variant of problems. The major contribution is the implementation of hybrid AAC_2_Opt algorithm to solve the DVRP and their performance to give competitive and high quality solutions.

The paper is structured as follows. Section 2 is devoted to the literature review of the existing papers that deals with the DVRP. In Section 3 we present the main definition and framework of the DVRP. Section 4 contains the description of our algorithm. In Section 5 we include the experiment results and the corresponding analysis to test our proposal algorithm. In Section 6 we conclude the paper.

2. Literature review

The VRP and its generalizations have been widely studied in recent years. In general, distribution problems are in the ability to meet requests from several customers (destinations) from one or several warehouses (sources), at lower cost. Normally, these problems are solved by placing the customers' demands in some way in vehicles of limited capacity. The academic researchers and private companies were motivated to conduct powerfully the transportation of goods and services.

2.1. Pick-up and delivery vehicle routing problem

For all the explosive growth in the VRP literature over the past several years, pick-up and delivery problems are a class of VRP in which objects or people have to be transported between an origin and a destination. Several routing problems with pick-up and delivery service are reported in the literature. The number of pickup, delivery, and service locations is the same in all transportation demands in the classical models. In the VRP all transportation requests are associated with a single pickup or delivery location. In the pickup and delivery problem (PDP) all transportation requests concern the pickup of a shipment at its origin and the delivery at its destination.

Little research in the VRP considers the multiple pickups, delivery, and/or service locations but we reflect on Savelsbergh and Sol [1] which represents the general pickup and delivery problem (GPDP) with multiple pickup and delivery locations.

In the GPDP a transportation request is composed of several shipments with different pickup and delivery locations. Each pickup location has to be visited before any delivery location. However, the sequence in which the pickup (or delivery) locations must be visited is not specified.

Ai and Kachitvichyanukul [2] propose a particle swarm optimization for the VRP with simultaneous pickup and delivery. Among publication that have explicitly addressed the pick-up and delivery VRP (PDVRP) we mention several papers, as Psaraftis [3,4] also Dumas et al. [5] which proposed a branch-and-price algorithm for the multiple-vehicle pick-up and delivery problem with time windows.

Nanry and Barnes [6] propose a reactive tabu search for the pick-up and delivery problem with time windows (PDPTW) in which the search progress is continuously analyzed and search parameters such as the length of the tabu list are adjusted accordingly during search.

Schonberger et al. [7] propose a genetic algorithm for solving the so-called pickup and delivery selection problem (PDSP) which extends the PDPTW by the decision of acceptance or rejection of transportation requests.

2.2. Dynamic pick-up and delivery vehicle routing problem

Until now, little research has been focused on the dynamic pickup and delivery VRP (DPDVRP), where problem size and parameters change after the vehicles are already commissioned. We consider the paper of Bertsimas and Ryzin [8] among the earliest work of the most basic DVRP which present an objective function with the waiting time and it describe a generic mathematical model. To our knowledge, very few published papers deal with the dynamic pick-up and delivery routing problem. Some further work can be found on Powell et al. [9] and Berbeglia et al. [10].

We present a general discussion of dynamic network modeling problems that arise in logistics and distribution systems, including a priori optimization and on-line decision policies for stochastic routing problems in Powell et al. [9]. Recently, Berbeglia et al. [10] surveyed the subclass of dynamic pickup and delivery problems, where the objects or people have to be collected and delivered in real time. The paper discusses various issues as well as solution strategies.

Since the first formulation of the VRP by Dantzig and Ramser [11], thousands of algorithms have been proposed for the optimal and approximate solution of the VRP, PDVRP and their variants (e.g. Euchi and Mraihi [33]). The immense popular of these algorithms distress the static VRP, i.e. it is unspecified that all data is known and invariant during resolution. Only recently dynamic problems have been increasingly premeditated in the vehicle routing literature. We present the most relevant literature on DPDVRP and in the solutions techniques devoted to it. A comprehensive discussion of DVRP can be found in Psaraftis [12] and Psaraftis [13]. In the literature, there are many methods and strategies have been proposed to tackle DVRPs.

Montemanni et al. [14] considered a DVRP as the extension to the standard VRP by decomposing a DVRP as a sequence of static VRPs and then solving them with ant colony system. Gendreau et al. [15] propose a tabu search heuristic for the DPDVRP with time windows. Hvattum et al. [16] presented an approach for problems where statistical information about orders appearance is available. A neighborhood search heuristics for the dynamic dispatching problem with pick-ups and deliveries has been applied in Gendreau et al. [17]. Savelsbergh and Sol [18] presented a planning module designed for a transportation company, which embeds a dynamic VRP module. A survey on results achieved on the different types of DVRPs can be found in Gendreau and Potvin [19]. Euchi et al. [20] proposes an artificial ant colony to solve the DVRP.

3. A framework of the DVRP

Dynamic routing goes beyond static routing by admitting the possibility of building/changing the vehicles routing solution online according to the current traffic events. It is useful to distinguish between the ability of adapting to the changing traffic conditions and to topological modifications (e.g., link/node failures, link/node addition/removal).

This section defines two different types of VRP: the static VRP and the dynamic VRP.

3.1. The static VRP

The static PDVRP is described in the following way: let $G=(V, A)$ be a graph where $V=\{0, 1, \ldots, n\}$ is a set of vertices and $A=\{(i, j): i, j \in V, i \neq j\}$ is a set of arcs. Vertex 0 is a depot at