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MOAMP-Tabu search and NSGA-II for a real Bi-objective scheduling-routing problem

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ABSTRACT

A bi-objective model for the design of daily routes over a planning period is analyzed. This model is proposed in response to a real problem encountered by a chemical analysis company located in Salamanca, (Spain). In order to improve its schedule for client visits, the company faced a two-level problem: first, to determine the days for client visits ("visit calendar") for each client during the planning period, and then to design the corresponding daily routes. To do so, two objectives were considered: minimization of transport costs and minimization of the number of changes to the existing calendar of visits. This model could be considered as a variant of the well-known periodic vehicle-routing problem (PVRP) with two objectives. A solution method that combines tabu search and MOAMP (Multiobjective Adaptive Memory Programming) strategies is proposed for this model. Also this method is compared with an adaptation of NSGA-II (Non-dominated Sorting Genetic Algorithm), a well-known strategy to multi-objective optimization. The computational results show that the MOAMP-Tabu Search method performs better.

1. Introduction

1.1. The PVRP and its development in the literature

The PVRP is a variant of the classic vehicle-routing problem (VRP). In the Periodic VRP, customers may require service on multiple days during a planning period. Customers must first be assigned to visit calendars (a set of visit days), and then the corresponding routes for every day of the planning horizon are designed. For example, customers requiring two visits a week might have the following calendars: Monday–Wednesday or Tuesday–Thursday or Wednesday–Friday. These two decision levels (assigning calendars to costumers and designing daily routes) are strongly connected. For this reason the PVRP is one of the most difficult VRP variants.

Beltrami and Bodin [3] were the first to propose a problem that involved a planning period longer than one day. They contributed two procedures for the solution of the problem: for the first, they developed routes and then assigned the days, in the second, they randomly assigned days to the clients and then solved the VRP using the algorithm of Clarke and Wright [12]. Over subsequent years, other works were published that continued along those lines. Some of them were by Russell and Igo [53], Christofides and Beasley [11]; Tan and Beasley [49] and Golden and Wasil [24]. These works may be considered to form part of the first stage of the PVRP.

In the 1990 s, Russell and Gribbin [46] proposed a four-stage heuristic for a solution to a PRVP. In addition, they suggested works that represented a small revolution when generating specific methods for the PVRP, as well as specific instances that have since been applied. Chao et al. [9] presented a two-phase method and then Cordeau et al. [13] used a heuristic based on tabu search, which permits non-feasible solutions during the search. Both algorithms have been a reference point for heuristics and subsequent algorithms.

Now in the 21st c., it is possible to find several works related with PVRP: in these works different solution methods have been proposed. Drummond et al. [16] proposed a genetic algorithm in parallel. Bertazzi et al. [4] proposed a constructive algorithm that included improvements, in which good quality solutions may be found in a simple way. Blakeley et al. [5] presented an expert software for the solution of this problem using a two-phase method; in the first, they made the assignation of days and workers to each of the clients and subsequently constructed the routes. Nuortio et al. [35] considered those two phases in inverse order.

In the work of Alegre et al. [1], a scattered-search heuristic designed to work with broad planning horizons is shown. The VRP solution is given by a heuristic based on greedy randomized

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adaptative search procedure (GRASP) and local search. Ronen and Goodhart [45] presented a work with 3 phases: cluster design, assignation of calendars and design of routes (in this case with commercial software). Pourghaderi et al. [42] proposed a constructive algorithm combined with scatter search. Later on, Méndez et al. [32] used memetic algorithms for the solution of the problem in two stages.

Another solution strategy that has been used over recent years is variable neighborhood search (VNS). One of its first applications was the proposal by Hemmelmayr et al. [27]. Peixoto [40] used a two-phase method: first, assignation of visit days and subsequently the design of routes. In the work by Pirkwieser [41], the so-called Multilevel VNS, (MVNS) was employed.

The great variety of heuristics to solve the PVRP, also include ant colony optimization (ACO). Thus, Yu and Yang [52] presented an interesting application that they called Improved Ant Colony Optimization (IACO), which consists in adding local search to the ACO strategy.

An interesting work is presented in Gulczynski et al. [26]. A heuristic is proposed in it that includes the use of entire programming to formulate parts of the problems, as well as local search with large-scale neighborhood. This work will be discussed below.

In [33] it is proposed a solution approach based on programming constraint (PC).This method combines a constructive procedure with a local search algorithm over a large scale neigborhood. Vidal et al. [50] presented a genetic method that they called Hybrid Genetic Search with Adaptative Diversity Control (HGSADC). Their objective was to exploit the qualities of both the genetic methods and the environment-based metaheuristics. Rademeyer and Bennetto [43] used a memetic algorithm where real operative restrictions were considered, such as the use of installations and capacity. Vahed et al. [54] proposed a methodology based on Path Relinking (PR).

Pacheco et al. [37] presented a model of real interest. This problem may be considered as a generalization of the capacitated VRP (CVRP) and as a particular case of the PVRP. The authors proposed a heuristic adapted to this model that combined GRASP with PR. Subsequently, Pacheco et al. [39] proposed a method based on VNS with memory for this model.

In Hemmelmayr et al. [28], another interesting variant with intermediate facilities was analyzed. This model has applications for waste collection and in inverse logistics. The authors proposed a VNS-based method. In Yao et al. [51], a method was proposed that combined ACO with local searches. In the work of Cacchiani et al. [7], a solution method was presented that began by considering the problem as a Set Covering Problem (SCP) with additional restrictions. The model combined linear relaxation, generation of columns and tabu search. Ray et al. [44] are explained the similarities among PVRP and other routing problems as Multi Depot or Multi Split.

Moreover, there are, to a lesser extent, exact methods that may be found in the literature for the solution of PVRP. The first appears in a work by Francis et al. [19] who proposed a PVRP where the possible delivery calendars for each client are considered as decision variables. Baldacci et al. [2] proposed different types of relaxations that find solutions to some instances of over 100 clients. Finally, Ngueveu et al. [34] presented a Branch-and-Cut method for a variant of PVRP, where each client is served once. Finally, it should be pointed out that a recent review of works on PVRP may be found in the compilation of Campbell and Wilson [8].

1.2. Multi-objective approach for the PVRP in the literature

Routing problems are ideal candidates for multiobjective optimization, because they arise in practical settings in which decision-makers confront conflicting objectives (such as service levels and costs).

There exists in literature several interesting works about multiobjective optimization in routing problems. These works analyses conflicting objectives such as cost, priorities, service levels. The work in multiobjective VRP until the early 1990′s is summarized in [14]. A more recent survey may be found in [30].

In general, the works in this field are mainly related to school transport, transport of dangerous goods, waste collection, and inverse logistics. As well as the reduction in the cost of operations, other objectives related to the level of service, danger, etc. are sought. Recently, the works of Pacheco et al. [38] on school transport and Gómez et al. [25] on waste collection may be highlighted.

There are not many references on multi-objective problems in the specific context of PVRP. Nevertheless, some interesting contributions may be found. For example, Smilowitz et al [47] presented a model in which, as well as operational costs, objectives referring to the management of staff contracted for that purpose. More recently, in [29], a generalization of PVRP was presented with applications for the planning of patrol car routes. In addition to minimizing the cost of the routes, they sought to maximize the number of lanes that the routes followed.

The model that is considered in this work is a model, based on a real problem, that is fitted with PVRP but with interesting characteristics (objectives and restrictions), other than those previously analyzed in the literature. Specifically, the considered objectives are to minimize the cost of operations and maximize the preferences of the clients. A method based on MOAMP (Multi-Objective Adaptative Memory Procedure) strategy, was designed to solve the problem. Subsequently, the quality of the method was evaluated with a second method based on the well-known evolutive strategy NSGA-II.

The rest of the work is organized as follows: in Section 2, the problem and its motivation are described; in Section 3, some similar problems are described that exist in the literature; in Section 4, the proposal of the problem is established, as well as different definitions, in Sections 5–7, the MOAMP method is described in detail (the generic description in Section 5 and the principal procedures in Section 6 and the routing procedures in 7); in Section 8, the NSGA II method is described for this problem; and, in Sections 9 and 10, the results of different computational tests (with simulated instances in 9, and with real data in 10). Finally, the conclusions are drawn in Section 11.

2. Motivation and description of the problem

In this work, a bi-objective model is analyzed for the design of the daily routes of a firm during a planning period. This model is based on a real problem that a Chemical Analysis firm in Salamanca proposed to the authors of this work. The firm is interested in improving the present-day planning, in other words, the design of daily routes as well as the assignment of visit calendars to clients. The objective of this new planning process was to reduce the costs associated with the routes. But on the other hand, the firm was interested in avoiding excessive changes to its existing calendars.

Normally, when a firm requests rationalization of its planning of product/service delivery to clients over a time horizon, it is seeking to reduce its operational (route) costs. However, this new planning is usually observed to differ significantly from the one used up until its introduction. In other words, it implies the modification of visit calendars and visit dates for many clients. These modifications are not usually welcomed by clients and can imply a certain loss of standing for the firm.

In consequence, when the problem is proposed, we should take two objectives into account: cost reduction and minimization of

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