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A heuristic approach for the Travelling Purchaser Problem

Jorge Riera-Ledesma *, Juan José Salazar-González

DEIOC, Facultad de Matemáticas, Universidad de La Laguna, 38271 La Laguna, Tenerife, Spain

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Abstract

The Travelling Purchaser Problem (TPP) is a known generalization of the Travelling Salesman Problem, and is defined as follows. Let us consider a set of products and a set of markets. Each market is provided with a limited amount of each product at a known price. The TPP consists in selecting a subset of markets such that a given demand of each product can be purchased, minimizing the routing cost and the purchasing cost. This problem arises in several applications, mainly in routing and scheduling contexts, and it is $\mathcal{NP}$-hard in the strong sense. A new heuristic approach based on a local-search scheme, exploring a new neighbourhood structure, is proposed. The key idea is to perform a k-exchange of markets instead of the classical 1-exchanges. A neighbour of a given TPP solution is another TPP solution obtained by removing a path of consecutive markets, and by inserting other markets so as to restore the feasibility. This proposal is evaluated on a broad class of instances from literature, where the routing costs are Euclidean distances. Computational results show that our proposal is favourably compared to previous heuristic algorithms in literature.

Keywords: Travelling Salesman; Heuristics

1. Introduction

This article is concerned with a generalization of the well-known Travelling Salesman Problem (TSP), known as the *Travelling Purchaser Problem* (TPP). The problem can be defined as follows. Let us consider a set of n products to be purchased and a vehicle originally situated at a domicile (location v_0). There is a given required demand for each different product. Let us also consider a set of m markets, each one selling some units (offers) of a certain number of products. The unit price of a product depends on the market. The travel cost between each two locations (domicile and markets) is also known. The TPP consists in selecting a subset of markets and routing the selected markets with a vehicle such that the demand of each product is satisfied and the total purchasing and travel cost is minimized.

The same combinatorial problem can be found in a scheduling context (see Burstall [3] and Buzacott and Dutta [4]). Indeed, let us consider a set of n jobs to be processed, and a multi-purpose machine, i.e., a machine that is able to perform m different configurations. Each job requires a given

* Corresponding author. Tel.: +34-922-319191; fax: +34-922-319202.

E-mail addresses: jriera@ull.es (J. Riera-Ledesma), jjsalaza@ull.es (J.J. Salazar-González).

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dedication (i.e. a set of tasks), while each configuration of the machine can execute only part of the dedication of the job. The processing time for each task of a job is given and depends on the configuration. Each task could be processed by different configurations, and each configuration could be used to perform tasks of different jobs. The time taken to change over from one configuration to another is also known. The machine remains initially in a default status (configuration v_0), status in which the machine must be after all the jobs are completely executed. The TPP consists in selecting and sequencing a set of configurations to fully execute the jobs minimizing the total processing and changeover time.

The particular case in which there is no restricted offer of a product at each market (or where each job consists of one task) is called *unrestricted TPP*. It can be seen as the TPP with one-unit demand for each product. It was introduced by Burstall [3] and by Buzacott and Dutta [4]. Other applications of TPP in Job Scheduling, Warehousing and Routing Problems are described in Singh and van Oudheusden [14]. The unrestricted TPP is known to be $\mathcal{NP}$-hard in the strong sense, since it becomes the TSP when each product can be purchased in only one market. Ramesh [13] described an exact method based on a lexicographical search capable of handling instances with $m \leqslant 12$ and $n \leqslant 10$. Singh and van Oudheusden [14] presented a branch-and-bound algorithm solving directed instances with $m \in \{10, 15, 20, 25\}$ and $n \in \{10, 30, 50, 100\}$, and undirected instances with $m \in \{10, 15, 20\}$ and $n \in \{15, 30, 50\}$. The bound in [14] is based on the *Uncapacitated Facility Location Problem* (UFLP), arising when the sequence requirement is relaxed. The TPP in the general case was first introduced by Laporte et al. [9]. In that article a branch-and-cut algorithm for the exact solution is also proposed and used to solve instances involving up to 200 markets and 200 products.

The literature on TPP is mostly directed towards the development of heuristic or near optimal methods. One of these heuristic procedures was introduced by Golden et al. [6]. The *Generalized Saving Heuristic* (GSH) is proposed in the article. This algorithm starts with an initial tour containing the domicile and the market selling the largest number of products at their lowest available price.

Their heuristic method was later on, modified by Ong [11] who proposed the *Tour Reduction Heuristic* which starts with an initial tour containing a subset of markets offering the n products and iteratively drops the markets yielding the largest cost reduction until no further improvement can be obtained.

Pearn and Chien [12] suggested some improvements to the two previous works of Golden et al. [6] and Ong [11]. Two of these improvements were related to the GSH of Golden et al. [6]. Another heuristic method proposed by Pearn and Chien [12] is called *Commodity Adding Heuristic*. This heuristic implicitly assumes that all products are available at all markets.

The first metaheuristic approaches for the TPP based on dynamic tabu search and simulated annealing are presented in Voß [15]. That article proposes two dynamic strategies for the managing of the tabu list: the *Reverse Elimination Method* and the *Cancellation Sequence Method*. Their impact on the TPP is also studied.

Another metaheuristic approach is presented by Boctor et al. [2]. Several algorithms based on tabu search are introduced and tested on TPP instances. The benchmark instances have been created for both the unrestricted and the general versions, and for the particular case in which the markets are locations in the Euclidean plane. These algorithms are tested on instances up to $m \leqslant 200$ and $n \leqslant 200$ comparing the obtained heuristic solutions with their exact solutions.

We propose an alternative heuristic approach for solving the TPP in the general version, i.e., with demands of products and offers at markets (or with jobs consisting of several tasks and limitations in the dedication of the configurations). The proposed heuristic is based on a local-search scheme using a special neighbourhood definition. The neighbourhood and the heuristic approach are specially designed for instances in which the routing costs are based on Euclidean distances (and particularly for the instances in [2]), but it could also be applied to solve other symmetric cost instances. The TPP is formally described in Section 2 and the proposed heuristic approach is detailed