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The Multiple Traveling Salesman Problem with Backup Coverage

Guilherme Dhein [1] Alberto Francisco Kummer Neto [2]
Olinto César Bassi de Araújo [3]

Universidade Federal de Santa Maria

Abstract

We consider a variant of the classical Multiple Traveling Salesmen Problem in which the distance between any two vehicles is never greater than a fixed distance D. This new feature allows salesmen to help each other timely if an emergency happens, with an estimated backup response time related to D. To achieve this goal, a spatial and temporal synchronization is required, and it incorporates routes interdependence difficulties to be overcomed. A Genetic Algorithm and a Local Search Genetic Algorithm that embodies a Variable Neighborhood Descent procedure are proposed to solve this problem. Computational results are reported on modified benchmark instances taken from TSPLIB in order to exhibit prospects of the proposed algorithms. Through an analysis of results, the highly effective performance of our proposed Local Search Genetic Algorithm is shown in comparison to the classical Genetic Algorithm.

Keywords: backup coverage, synchronization, Genetic Algorithm, VND

[1] Email: gdhein@redes.ufsm.br
[2] Email: alberto@inf.ufsm.br
[3] Email: olinto@ctism.ufsm.br

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1 Introduction

The Multiple Traveling Salesmen Problem (mTSP) can be seen as a relaxation of the Vehicle Routing Problem (VRP). Both problems present sets of tours as solution, but in mTSP there are no constraints regarding vehicles capacities and clients demands.

In a more formal way, mTSP can be defined as the problem of finding tours on an undirected graph $G = (V, E)$, where $V = \{0, 1, ..., n\}$ is the set of $n + 1$ vertices, and $E = \{e_{ij} \mid 0 \leq i \leq n, 0 \leq j \leq n\}$ is the set of edges connecting pairs of vertices in V. A cost c_{ij} is associated with every edge $e_{ij} \in E$ to represent the travel time from i to j. There is a set $K = \{1, 2, ..., m\}$ of identical vehicles, and a solution is a set of m tours, each one assigned to a vehicle. All vehicles depart from vertex 0 (depot) and finish their tours back at depot. Each vertex is visited only once, by one vehicle.

We address a new mTSP generalization, called Multiple Traveling Salesmen Problem with Backup Coverage (mTSP-BC). In this problem, the instantaneous distance between any two vehicles k and l cannot exceed a maximum distance defined as a parameter D. The relative distance between any two vehicles is calculated over the entire solution, even if one of them already finished its tour and is back at depot. An ordered pair of coordinates (x_i, y_i) is associated to each vertex $i \in V$, allowing the calculation of vehicles positions at any moment. Every time a vehicle reaches a vertex, we calculate the current positions of the other vehicles to obtain the distances. As in mTSP, the objective of mTSP-BC is to minimize the sum of distances traveled by each salesman. The problem is obviously NP-hard, because each instance of mTSP may be solved as an instance of mTSP-BC in which D is large enough.

The new constraint forces vehicles to travel close to each others. This means that in a case of contingency involving one vehicle, the parameter D establishes a backup response time. This behavior can be useful in real routing activities carried out in hostile environments.

Vehicles relative distance constraint represents a major difference between mTSP and mTSP-BC solutions. In mTSP, tours established as sequences of vertices with spatial proximity are interesting, because they present edges with low cost. Also, the tours are independent, and a modification in a tour may be evaluated only locally. In mTSP-BC, this spatial proximity of subsequent vertices is also important, since the objective function is the same. But it is also important to designate vertices with spatial and visit time proximity to different tours, in order to guarantee feasibility. There is a degree of synchronization between visits to vertices with spatial proximity, which implies