Heuristic Solutions for the Trigger Arc Traveling Salesman Problem: An Application of GRASP

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Abstract

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***K*eywords** TSP · TA TSP · GRASP · Local Search · Trigger Arc TSP · Optimisation

1 Introduction

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2 Background

2.1 The TA TSP

The Trigger Arc TSP (TA-TSP), is a variation of the TSP introduced by Cerrone et al.[1]. Unlike traditional TSP formulations, which typically assume static or purely time-dependent arc costs, the TA-TSP incorporates a dynamic cost mechanism that directly reflects the sequence of traversed arcs within a tour.

Specifically, this problem introduces a set of Relations, comprising two distinct arc types:

- Trigger Arcs: These are designated arcs whose traversal can influence the cost of other arcs within the network.
- Target Arcs: These are arcs whose traversal cost is subject to dynamic modification.

Each relation defines a specific cost that a target arc will assume if its corresponding trigger arc is the last trigger arc visited immediately preceding the target arc's traversal. This mechanism is critical, as it establishes a pronounced path-dependency, making the total tour cost contingent on the specific sequence of arcs traversed.

A formal definition of the problem is given by Cerrone et al. [1] as: consider a directed graph $G = (N, A)$ with weights on the arcs. The node $0 \in N$ is designated as the starting node (depot). Let $c(a) \in \mathbb{R}^+ \forall a \in A$ be defined as the cost of traversing the arc a. For each arc $a = (h, k)$, a set of relations $R_a = \{(a_1, a) | a_1 \in A\}$ is associated. Finally, let $c(r) \in \mathbb{R}^+ \forall r \in R_a$, be the traversal cost of the arc a if the relation r is active. Let $T = (a_1, a_2, \ldots, a_{|N|})$ be the ordered sequence of arcs starting at node 0 representing a Hamiltonian cycle in G. The relation $r = (a_i, a_j)$ is active if and only if the arcs $a_i, a_j \in T$, and the arc a_i precedes the arc a_j in T and there is no active relation $r_1 = (a_k, a_j) \in R_{a_j}$ such that a_k precedes a_i in T. It follows that for each arc a, at most one relation can be active. As a result, the traversal cost of the arc $a = (h, k)$ will be equal to $c(a)$ if there are no active relations in R_a or $c(r)$ if r is the only active relation in R_a.

This particular problem formulation is designed to facilitate the modeling of complex real-world scenarios where the act of traversing an arc by a vehicle or agent can intrinsically alter the properties or costs associated with subsequent segments of the underlying road network or system state. Building upon its initial definition, this work further investigates the TA-TSP, aiming to explore its properties and develop methods for its resolution.

2.2 The GRASP approach

The solution developped in this paper mainly rely on a proven metaheuristic introduced by Feo et al.[2], the Greedy Randomized Adaptive Search Procedures (GRASP). This powerful and flexible framework is well-suited for tackling complex combinatorial optimization problems, including those exhibiting the intricate path-dependencies seen in the TA-TSP. It operates through an iterative two-phase process: a construction phase and a local search phase.

The construction phase leverages a greedy randomized strategy to build a feasible solution. This involves creating diverse fea-

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sible solutions at minor computationnal costs. The diversity of the solution is carried on by a degree of randomness.

Following the construction of a solution, the local search phase then systematically explores its neighborhood to improve it, typically by applying moves that lead to better objective function values. The best solution found across multiple iterations of these two phases is ultimately returned.

This rigorous yet adaptive approach makes GRASP particularly well-suited for problems where the optimal solution is difficult to find through exact methods.

3 Methodology

Overview of the approach

3.1 Constructing initial solution

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3.2 Local search

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3.2.1 Delta evaluation

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4 Experimental Setup and Data

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4.1 Datasets

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5 Results and Discussion

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6 Conclusion

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