TAOR Mid Report

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February 2023

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1 Introduction

The commercialization of Unmanned Aerial Vehicles (UAVs), which is known as drones, brings a transformative element for small parcel delivery and associated delivery routing problem. The remote operation of drones, their relative economy in delivering to isolated locations, and their speed is compared with ground vehicles all make them into an appealing option for people to choose. Currently, many countries including U.S. and U.K. have allowed remote operation of drones boarding by setting some regulations of the sights and routines.

In this project, we study the Traveling Salesman Problem with Drone (TSP-D) and its improvement by using 0-1 mixed-integer problem (MIP). There are many academic literatures presenting modelling approaches showing the problem under different settings of the considerations of the aspects that attract people. Combining the models in the literatures, we focus on the strength of each one and make the improvement of the modelling and methodological, and computational perspectives. For the modelling and methodological part, we use valid inequalities, instance pre-processing and parameter scaling strategies to improve the model; for the computational part, we make the approach to enable exact solutions for benchmark and with some simulating breaches.

2 Optimization model

Objective model: minimize the return time of both the vehicle and the companion drone to the depot.

Constraints consideration:

- Both the vehicle and the drone depart the depot for exactly one destination.
- The drone must visit the node that the vehicle does not visit.
- The vehicle must visit at least one of the nodes of the drone's flight arcs.
- The drone fly from the nodes if they are not transported aboard the vehicle.
- If the drone flies between two nodes, the flight must travel from two nodes with same direction.
- For a given flight, the drone can travel for at most a duration of the maximum flight duration for the drone to make a single delivery.
- Travel and departure constraints according to Miller-Tucker-Zemlin-type subtour.
- Vehicle waiting time equal to the difference of the actual and expected departure times from a node.

- The vehicle's waiting time is equal to the difference if the drone departs a node later than the vehicle.
- The limitation of the lower bounds for the value of the arrival time at the depot.

3 Bound improvement strategies

In order to strengthen Model TSP-D, we plan to make lower bound improvements and upper bound improvements on the original problem.

When making lower bound improvements, we can improve the objective value of the continuous relaxation of Model TSP-D. We can achieve this by introducing a series of valid inequalities and by tightening "M" scalars in the formulation.

And when making upper bound improvements, we will initialize the solver with a "warm" start, in which a feasible objective value with associated integral variable values are specified, overcoming the problem that it is difficult for the algorithm to generate good feasible solutions in early stages.

4 Computational study

In this section, we will present computational results of our TSP-D. The problem will be solved using Gurobi version 10.0.1. In this process, we will assume that: the speed at which the drone travels is twice the speed of the vehicle; all nodes are eligible for service by the drone; and each drone's maximum travel duration during one flight is limited to 30 minutes.

The instances we use are offered by Bouman, Agatz, and Schmidt[1], which were designed for the TSP-D. We might focus on three types of topographies, which are single-centre (SC), dual-centre (DC), and uniform (U) topographies. We will pre-process these instances, to make them more suitable for the focus of our research.

After getting the results, we will summarize them, making detailed tables for each instance we use. In the tables, we will report the number of instances solved optimally, the average number of branch-and-bound nodes explored by the solver, the average of the total computational effort of the multi-step solution procedure, and the average MIP gap reported by the solver at termination.

Also, we will assess the bound improvement we conducted on the original MIP model. Sensitivity analysis of maximum drone flight duration will be conducted too.

5 Conclusion

We began with our novel mixed-integer program(MIP) for the Traveling Salesman Problem with Drone, and enhanced the model through employing cut generation and bound improvement strategies. We have not got the results, but according to *Parcel delivery by vehicle and drone*, which is the article that we refer to, our computational study will report optimal solutions for instances with up to 24 nodes. Also, we will be able to solve problems having 28 and 32 nodes when breaches are encouraged. Thus, the study will expand the range of solved instances in previous studies.

Apart from the computational results, we intend to summarize some innovations and contributions that will be made by the research. The disadvantages of our study will also be generated. Besides, we will list new techniques we want to use and new topics we want to study in future TSP-D research. The new techniques can include dynamic programming and decomposition techniques. And the new topics might involve networks with multiple depots and the possibility for one vehicle to operate several drones.

References

[1] A. N. . S. M. Bouman, P., "Instances for the tsp with drone (and some solutions)," https://doi.org/10.5281/zenodo.1204676, accessed: 2023-01-29.