Environmental Monitoring by Deploying Autonomous Unmanned Vehicles

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1 Introduction

The use of autonomous unmanned vehicles, such as drones or robots, is not a new a new topic. They find many applications in different sectors, not matter with military or civil objectives. In the civil sector, we observe increasing use of autonomous vehicles, for example, in delivery services, surveillance, and also environmental protection. The latter one is mainly done through monitoring operations. In this context, the primary objective consists in collection data, e.g., taking pictures from a zone. For this purpose, the autonomous unmanned vehicles have the required equipments, e.g., cameras, sensors, etc. Using such technologies, an autonomous unmanned vehicle can perform spatial mapping of a zone, detect pollutant leaks, take pictures, an so on (see, e.g., [1, 4, 5, 6]).

Using autonomous unmanned vehicles have multiple advantages, e.g., reduced costs, flexible deployment schedule, safer operations, high precision, access to risky or difficult-to-reach zones, etc. However, an efficient use of this technology requires some logistic operations, i.e., planning the trajectory to minimize the operational costs, reduce mission time, and so on [3, 4, 7, 8, 9]. This project is defined and implemented in this perspective. More precisely, we define, formulate, and solve the *Generalized multi-visit multi-drone Covering Salesperson Problem with Varying Coverage* (GmCSP-VC).

2 Description of the problem and the results

This study focuses on the *Generalized multi-visit multi-drone Covering Salesperson Problem with Varying Coverage* (GmCSP-VC), which consists of using multiple main vehicles equipped with some assistant autonomous vehicles with the objective of monitoring a given set of locations in minimal time. More precisely, we aim at routing a fleet of heterogeneous vehicles, composed of a set of main vehicles, each of them equipped with an equal number of identical assistant autonomous vehicles, to monitor a given set of points in the minimum time. In this context, the monitoring is define by either visiting a location, or covering it. The latter one is accomplished by arriving to a predefined neighborhood of the location. This problem can be considered as an extension to the classical *Vehicle Routing Problem* (VRP) as we have a fleet of multiple vehicles.

The GmCSP-VC can be formulated as a *Mixed Integer Linear Program* (MILP). The MILP model of the GmCSP-VC consists of the objective function, the makespan that should be minimized, subject to multiple constraints, e.g., constraints for flow conservation, synchronization of vehicles, timing, etc.

Since GmCSP-VC is a challenging optimization problem, the classical tools and commercial solvers, e.g., Gurobi Optimizer or IBM CPLEX, may be used to address only small instances. In this study, we have the following contributions:

- We use the MIP solver Gurobi Optimizer to address small-sized instances.
- To address larger GmCSP-VC instances, we introduce a heuristic algorithm [2].
- We present the numerical results of our extensive computational experiments, which confirm the efficiency of our approaches. Indeed, according to the computational experiments on the benchmark instances, our algorithm provides high-quality solutions.

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