Computers and Operations Research CAOR-D-21-00152 "Coordinating drones with mothership vehicles: The mothership and drone routing problem with Graphs"

Answer to Reviewers' Comments

May 25, 2021

We wish to thank the Editors and the Reviewers for their valuable comments and advices which allowed us to further improve the quality of our paper.

We revised the manuscript by taking into account all the suggestions of reviewers 1 and 2. We report below our changes inside the colored textboxes.

Editors' Comments

The reviewers have commented on your above paper. They indicated that it is not acceptable for publication in its present form. However, if you feel that you can suitably address the reviewers' comments (included below), I invite you to revise and resubmit your manuscript. You will find your submission record under the menu item, 'Submissions Needing Revision'. Please carefully address the issues raised in the comments.

Answer E

Thank you for the feedback. We revised the manuscript following the reviewers' advices. We outlined in blue each change made in the revised version of the paper.

Reviewer 1

While the authors motivate the use of drones (also in combination with a mothership) in general, their problem/model formulation is not motivated by a practical example. It remains unclear to me why they study this problem, and whether it has any practical application.

Answer R1.1

Thanks for the comment. In section 1 of the revised version of the manuscript we further highlighted the practical applications of the model we proposed. Any inspection and surveillance operation to be performed by a drone following a polygonal path, can be planned by using our model. Practical examples of this, in which the use of a drone is safer, are video-surveillance of streets, inspections of pipelines to prevent damages and terrorist attacks, reconnaissance activities to estimate the damages caused by natural disasters on railway or road networks and others. In all these examples, the support of the mothership vehicle is required for dealing with the limited endurance of the drone. However, we point out that the contribution of our manuscript is also methodological.

The problem definition is highly unclear to me. I like the idea to introduce the problem before giving an overview on the literature, as tried in section 2. But then, Section 2 needs to be self-contained. If no technical problem definition is given there yet, then at least a clear intuition on the problem should be provided. But for me, Section 2 has the opposite effect. As a reader, I leave this section more confused than I was before, without knowing which decisions are in scope of the models, what constrains them, and what the objective is.

Answer R1.2

Thanks for your feedback. In the revised version of the manuscript, we modified section 2, also adding a more complete description of the problem and a picture showing an example of the problem framework.

Section 3 starts more technical, but also here the format of variables and input is not always clear. I have struggled with this for a while, and then given up on it.

Answer R1.3

In the revised version of the manuscript we inserted in section 4 tables summarizing all the input parameters and decision variables for each version of the problem and related proposed formulations, in order to make the section clearer.

I do think that this paper may have its merits, justifying a publication, but we would first need a clear problem definition, to be able to understand the problem and to appreciate the rest of it. I therefore advise to ask the authors to undertake a major revision.

Answer R1.4

Thank you for your comments. We took into account all your suggestions to improve the presentation and the quality of our paper. As for the merits justifying publication, we have to emphasize that we have presented a full methodological overview of formulations for the coordination of a base vehicle and one drone that before were not properly given in the literature. We compare different ways to model this coordination and report exhaustive computational experiments on the different models.

Section 2
This problem description did not succeed to give me a clear picture of the problem. I did not understand the motivation (which real-life problem are the authors intending to model?), nor did I properly understand the constraints, which decisions are made by the models (what is variable, what is given?), nor is the objective clear.

Answer R1.5

See answers R1.1 and R1.2.

A few more detailed comments on problems I encountered during reading this section can be found below. Page numbers refer to page numbers as displayed in Acrobat reader.
1. p3 "Moreover we considered.." : why is past tense used here

Answer R1.6

Thanks for carefully reading our manuscript. We changed this verb to the present tense.

2. p3 "... and e_g that denotes..." is not a proper (half)sentence.

Answer R1.7

We agree with you. In the revised version of the manuscript we removed from this point this sentence and we wrote, in section 4, the sentence "Let e_g be edge e of the graph $g \in G$ and let $\mathcal{L}(e_g)$ be its length."

3. p3: 1.The mothership is not a description variable, rather its position is described using a decision variable. 2. In what way does x_L^t describe the position of the mothership at time t? Is it a set of coordinates?

Answer R1.8

Thanks for the comment. The position of the mothership at stage t is described by the decision variables x_L^t and x_R^t representing pairs of coordinates respectively of the point from which the mothership launches the drone and of the point where the mothership retrieves the drone after visiting one of the targets. We better clarified this also in the revised version of the manuscript.

4. p3 What do you mean when you say that target locations are "modeled by graphs"? And then later on this page, that the drone traverses "the required portion of graph g"? What is the "total length" of a graph? Is it the sum of edge lengths? Do graph edges even have lengths? (not explicitly specified up to the point where the total length is introduced) Make sure everything is defined before you use it.

Answer R1.9

Thank you for the questions and suggestions. We modelled the targets to be visited by the drone, representing for example streets surrounding neighborhood blocks to be inspected, as graphs whose edges must be traversed by the drone.
Moreover, we assumed the possibility that only a given percentage of each of these graphs, or of each of their edges, must be visited. However, in the revised version of the manuscript, in order not to confuse at this point of the problem description, we modified this sentence in "the drone traverses the edges of graph g".
In the revised version of the manuscript we introduced the length associated with each edge and we explicitly defined the length of the graph g as the sum of the lengths of its edges.

5. p3: What does "entry and exit points" refer to? Entry and exit to a graph? Or to an edge? How should I understand that? Is the graph embedded in the plane? Are at least the entry and exit points embedded in the plain? What do the tupels that they consist of stand for? Can a drone move in the plain between different points fo the graph? Are these entry and exit points variable or input? $\mu_g^e = 1$ even if e_g is visited only partially?

Answer R1.10

The entry and exit points are associated with each edge of each target graph and they refer to the points from which the drone enters in and exits from the edge for visiting it. In the revised version of the paper we changed the notation for defining these points and we adopted $R^{e_g} = (B^{e_G}, C^{e_g}, \rho^{e_g})$ and $L^{e_g} = (B^{e_G}, C^{e_g}, \lambda^{e_g})$ to indicate that the coordinates of point R^{e_g} and L^{e_g} are computed as function of the ones of the endpoints B^{e_G} and C^{e_g} of edge e_g and the variable parameters $\rho \in [0, 1]$ and $\lambda \in [0, 1]$.
The entry and exit points so defined are variables by means of the variable parameters ρ and λ to be determined by solving the model.
The target graphs are located in the plane and the drone is free to move between different points of each graph.
The variable μ_g^e indicates if edge e of graph g is visited, independently if the drone visits the whole edge or only a given percentage of it.

6. What is the intuition/motivating application behind this model?

Answer R1.11

See answer R1.1.

7. To understand the constraints on page 4, it would extremely help if we knew what the variables and parameters in this constraint stand for, and which of them are actually variables and which are parameters. I must admit that this remained unclear to me. After having made some guess that appeared to be inconsistent with the formulation, I kindly ask the authors to explain

this better. I think an illustrative example (in addition to an unambiguous description)would also help here.

Answer R1.12

We agree with you and in the revised version of the manuscript we added further explanation of these constraints, clarifying what is variable and what is parameter.
Moreover, as you suggested, we added an illustrative example at page 7 of the revised version of the manuscript, to better clarify the two ways of visit of the target graphs.

8. p4: The "goal" is unclear to me. What is a "minimum time path"? Do you measure time from departure at dep to arrival at arr, as often done in the literature, or do you consider "overall weighted distance", as stated in the abstract. If so, what are the weights? The speed factors?

Answer R1.13

The goal is the minimization of the distance travelled by both the mothership and the drone. Because we assumed constant velocity for both mothership and drone, this implies also the minimization of the time required to perform the visit of all target graphs in the framework we studied. In the revised version of the manuscript we further clarified this issue.

1. page 6: Are Reg , Leg given?
2. p7: "we can model the route that follows the drone" → "we can model the route that the drone follows"
3. p7: interior/exterior edges are not defined
4. p7: no description of constraint (5)
5. p7: What is μ?
6. Does the word "clusterize" exist? Wouldn't "cluster" be more common?

Answer R1.14

Thanks for these remarks. We corrected all of them in the revised version of the manuscript.

Reviewer 2

The paper provides a small but relevant contribution to the growing body of "drone-related" literature. While a vast number of papers focus on delivery drones, here the drone has to cover the edges of target graphs.

Unfortunately, the motivation for a "visiting percentage" parameter for the target graphs seems to be unclear. While it is certainly possible to ignore it by setting it to 100% the reader remains curious for an applications scenario which remains obscure.

Answer R2.1

Thanks for the observations. As we also highlighted in the revised version of the manuscript, many different inspections and monitoring activities can be performed by drones in a systematic and safe way. We can mention, for example, monitoring of the status of bridges and portions of road networks, both for preventive maintenance and for inspection after disasters (e.g. earthquakes). Other kind of inspection activities, like for example video surveillance of urban areas of big cities, can be also modelled by adopting the formulations presented in this paper. In this context the request of visiting only a given percentage of the target graphs (e.g. borders of a neighborhood) can be due to the necessity of "covering" different areas in a limited amount of time. Another example that we can mention is the traffic flows monitoring. In this case, in order to verify if the traffic progression is not disrupted, only inspecting a portion of edge provides a valuable information.

The paper is well written but rather long. This raises the question for potential shortening: I would opt to shorten the lengthy and recurring discussion of "MTZ vs. SEC"-formulation and focus on the superior one (based on your experiments). Also the Big-M strengthening might be shortened without too much loss. On the other hand, the Matheuristic section would benefit from discussing the motivation of your design choices in contrast to potential alternatives in more detail.

Answer R2.2

We have followed the suggestions raised by the referee and we have shorten and moved the big-M strengthening to an appendix so that the reading of the paper is more fluid and still some details on the bounds can be found by the interested readers.
Moreover, we have added a more detailed explanation of the different phases of the matheuristic. The new paragraph explains the rationale of our approach. It reads as:
Since dealing with the exact model is a hard task for medium size instances, we have adopted the approach to split the problem. The rationale of this algorithm rests on decomposing the problem in simpler subproblems decoupling the decisions made on the route followed by the mothership and the ones made on the drone. To do that, first we solve a XPPN for the mothership assuming that targets graphs reduce to small neighbors around their centroids and then we solve drone operations one at a time based on the order previously defined for the mothership. In this way each subproblem is much simpler and once their solutions are found one can integrate them into a feasible solution of the whole problem.