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Data Collection Planning with Limited Budget for Dubins Airplane

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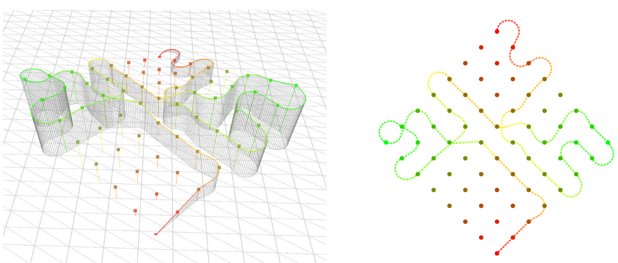
In this work, we address data collection planning with an *Unmanned Aerial Vehicle* (UAV) motivated by surveillance missions in which the UAV is requested to take snapshots at the given set of target locations. In particular, we focus on scenarios where UAV can be modeled by the Dubins airplane model [1] in 3D and the travel budget is limited. In these problems, each target location has associated reward value representing an importance of the target, and thus the studied planning problem is to determine the most valuable targets together with the sequence to their visits such that the length of the data collection trajectory fits the travel budget.

The introduced problem is called the **Dubins Airplane Orienteering Problem** (DA-OP) as it is a variant of the existing *Orienteering Problem* (OP) [2] extended for the Dubins airplane model to address constraints of fixed-wing UAVs [3]. The DA-OP can also be considered as an extension of the previously introduced the *Dubins Orienteering Problem* (DOP) [4], [5] and its further generalization the *Dubins Orienteering Problem with Neighborhoods* (DOPN) [6], [7]. Contrary to our previous work, the DA-OP formulation addresses data collection planning in 3D where climb and dive angles are limited in addition to the minimum turning radius of the regular 2D planning with Dubins vehicle.

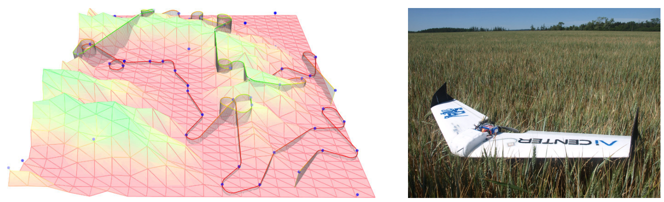


(a) Found solution (b) 2D projection

Fig. 1. A solution of the DA-OP instance modified from the standard OP benchmark Set 64 [8] with 64 targets for which the altitude of the target depends on the reward associated to the target

We propose to solve the DA-OP by a randomized version of the Variable Neighborhoods Search (VNS) algorithm [9] for which the vehicle headings are uniformly sampled, and the length of the maneuver connecting each pair of possible vehicle states is precomputed. Based on our empirical evaluation, we found that 16 heading samples per each target provide a suitable trade-off between the computational requirements and the quality of the found solution.

An initial solution is generated greedily by a repetitive insertion of the target location with the best ratio of the reward to the trajectory prolongation until the maximum travel budget is reached. Then, the VNS algorithm optimizes the current solution by applying four different neighborhood structures (operators). First two operators (insert and exchange) randomly change a part of the current solution to explore the configuration space and possibly escape from local minima. The two additional operators (path insert and path exchange) optimize the solution by applying n^2 randomly generated modifications where n is the number of all targets. An example solution is depicted in Fig. 1.



(a) Planned 3D trajectory (b) Fixed-wing UAV

Fig. 2. A solution of the introduced Dubins Airplane Orienteering Problem (DA-OP) found by the proposed VNS-based solver. Target locations are in the blue and the color of the found trajectrory represents the altitude (from the red for the lowest to the green for the highest).

Our early results on the modified OP instances to the introduced DA-OP indicate the VNS-based algorithm is a suitable approach for the DA-OP which is able to find solutions of a reasonable quality. We further plan to address planning of 3D trajectories in terrains with varying elevation and their experimental validation using a real fixed-wing UAV as shown in Fig. 2.

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