Bi-objective Energy-Efficient Maximal Coverage Path Planning for UAVs

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1 Introduction

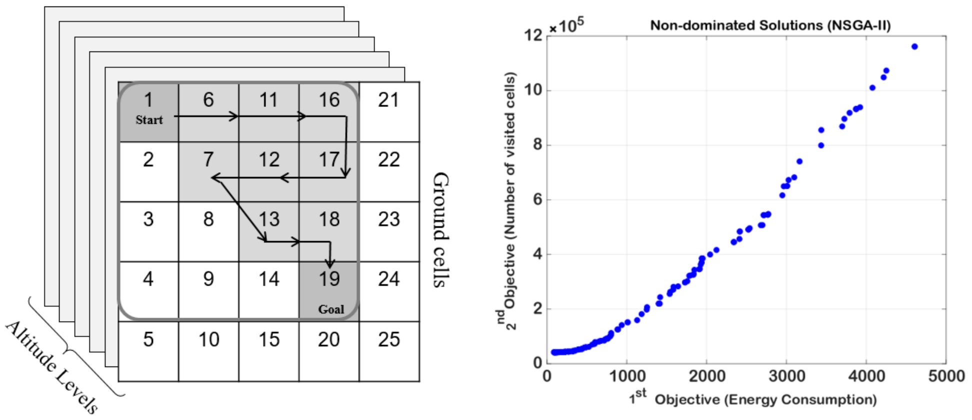
Path planning is one of the key factors for autonomous navigation of an aerial robot (e.g. Unmanned Aerial Vehicle (UAV)) which has recently attained high popularity among researchers considering various types of UAVs. Coverage path planning for UAVs is the task of determining a path that passes over all points of an area of interest. The path determination for the UAVs should be free from all collisions with the surrounding obstacles while satisfying the physical and kinematic constraints. Several versions of UAV path planning problems have been investigated in the related literature [2].

In this study, we present a novel discrete bi-objective energy-efficient maximal coverage UAV path planning problem. Here, the ground space is decomposed into several equal-size cells (Fig. 1 (a) shows an example of the environment modeling). The flying altitude of each cell should be greater than the height of existing obstacles, if any. Considering both the possibilities of bypassing the obstacles or adjusting the altitude to fly above them, while minimizing the consumed energy, the number of visited cells is maximized. Using a new solution representation and customized mating operators, non-dominated sorting genetic algorithm–II (NSGA-II) is applied as the solution method [1]. The effectiveness of the proposed model is validated through several random test cases.

2 Methodology

Although UAV path planning problems need to be studied based on different criteria, the majority of maximal coverage path planning problems are studied in a single objective context. On the other hand, static obstacles are typically considered as prohibited airspace and therefore, shortening the path length by adjusting the altitude and flying above them is not possible. This study aims to overcome these shortcomings by considering both possibilities of bypassing the obstacles or flying above them in a bi-objective structure in which the first objective minimizes the consumed energy while the second objective aims to maximize the number of visited cells.

Each solution is represented by a matrix of two rows. The first-row genes indicate the index of visiting ground cells, while the corresponding second-row genes represent the adjusted altitude just prior to entering that cell. The first-row initiates with the index of origin. For each first-row gene, the succeeding gene is filled by the index of a randomly selected not-visited neighbor cell. This procedure is continued until visiting the destination. If all the neighbor cells are used to fill the previous genes, the destination is not reached and the solution will be infeasible. The second-row genes are filled by a randomly generated integer number in the



(a) (b)

FIG. 1: (a) An example of environment modeling (gray cells are the covered area) (b) The obtained non-dominated solutions

range of the corresponding first-row cell's obstacle height (if any) and its maximum allowed flying altitude. Moreover, this study applies the one-point crossover operation to generate two offspring chromosomes by mating two selected parental chromosomes based on ranking-based roulette wheel selection. The crossover point is chosen randomly along the length of the mating chromosomes and decomposes them into two segments. Suppose that C is the position of the crossover point. Considering the first-row genes, if the $C{+}1^{th}$ allele of the second parent is among the neighbourhood set of the C^{th} allele of the first parent, the first child is generated by merging all the first segment of the first parent with all the second segment of the second parent. Otherwise, until reaching a point by which merging the parents is possible, the crossover point will be iteratively shifted to the right-hand side for the selected parent or for both of the parents.

Since any further change in the first-row genes requires a corresponding search and repairing procedure that was explained in the crossover section, the mutation operation is applied to the second-row genes. Based on the mutation probability, a random number of second-row genes are selected, and using the probabilistic procedure previously mentioned about filing the second-row genes, their alleles are replaced with randomly generated numbers.

3 Conclusions and perspectives

In this study, we investigated the discrete bi-objective energy-efficient maximal coverage path planning problem for UAVs where the consumed energy is minimized and the number of visited cells is maximized. The results show the effectiveness of the applied NSGA-II algorithm in solving the new problem definition through several generated test cases (Fig. 1 (b) shows the obtained non-dominated solutions for one of the test cases). It might be interesting to offer other objectives in order to address the uncertainties.

References

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