Information-Based Path Planning for UAV Orchard Coverage

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1 Introduction

Unmanned aerial robots (UAVs) are commonly used to perform field coverage activities. In certain applications, as in precision farming, these vehicles must fly at very low speeds and not surpass certain altitude limits. With these constraints, covering vast areas with a single flight becomes unrealistic in terms of flight time. This situation is encountered in the EU project PANTHEON "Precision farming of hazelnut orchards", where the farming areas exceed hundreds of hectares.

Remote monitoring of large-scale areas is addressed in the literature as a covering problem or as an orienteering problem. In the covering problem [1], multiple paths are calculated and combined to cover the whole area. In the orienteering problem [2] instead, single paths are calculated to maximize a specific objective function at each flight.

In this contribution, we present a path planning strategy to cover an orchard while prioritizing the amount of information obtained during each flight. In the PANTHEON project, a Kalman filter is used to estimate the current health status of the plants. This observer works with temporally and spatially sparse measurements given by fixed soil sensors and the cameras mounted on the UAV. In this work, we plan to decide on the trajectories of the UAV such that the performance of the observer is improved.

2 Problem Statement

The surface to be covered is discretized based on the camera sensor requirements and considered as an undirected and connected graph $G = <V, E>$. The set of vertices V represents the points where the pictures can be taken and the set of edges E represents the allowed trajectories of the UAV. The coordinates of the vertices are calculated based on the characteristics of the cameras, i.e. the field of view. Additionally, each vertex $i \in V$ has a maximum degree of 4 to ensure the continuity between pictures and the possible creation of a valid orthomosaic. The edges $(i, j) \in E$ have a weight t_{ij} representing the time to travel from vertex i to vertex j, whereas the score at each vertex S_i is based on the performance of the Kalman filter at the corresponding point of the orchard.

Given similar conditions, common applications try to obtain a shortest path, which starts and finishes at a given point of the grid. However, when the time constraint is clearly smaller than the diameter of the graph, there is a strong dependency between the initial point and the resultant path. To ensure the global optimal path, we add two "external" nodes with directed edges connected to all vertices and with smaller time weights. These vertices are imposed as initial and final points of every path. This concept can be seen in Figure 1.

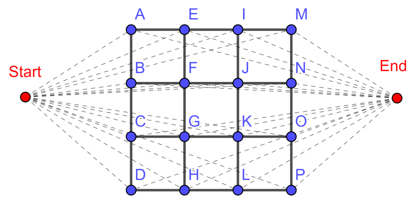

Figure 1: Schematic of the graph distribution

The problem can then be formulated as an integer linear programming (ILP) problem, where the objective function to be maximized is

$$\sum_{i=2}^{N} \sum_{j=2}^{N} S_j x_{ij} \tag{1}$$

S_j being the information obtained by visiting the node j and x_{ij} a boolean decision variable, where x_{ij} is 1 if the UAV travels from node i to node j and 0 otherwise.

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References

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