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Coverage path planning for UAVs based on enhanced exact cellular decomposition method

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ABSTRACT

In this paper, an enhanced exact cellular decomposition method to plan the coverage path of UAVs in a polygon area is proposed. To be more specific, the contributions of the paper are: firstly, the turning motion of UAVs is shown to be less efficient from the viewpoints of route length, duration and energy. Secondly, the problem of Coverage Path Planning (CPP) in a convex polygon area is transformed to width calculation of the convex polygon, and a novel algorithm to calculate the widths of convex polygons with time complexity of $O(n)$ is developed. The path of the least number of turns for an UAV based on the widths of convex polygons is devised. Thirdly, a convex decomposition algorithm for minimum width sum based on the greedy recursive method which revolves around decomposing the concave area into convex subregions is developed. It is proved that the algorithm is a polynomial time algorithm. To avoid unnecessary back and forth motion, some entirely adjacent subregions are combined. Finally, comparing different weights of two joint-points, a subregion connection algorithm based on minimum traversal of weighted undirected graph is proposed to connect the coverage paths of the subregions. Simulation results show that the proposed method is feasible and effective.

1. Introduction

Over the past decade, there has been a great demand of Unmanned Aerial Vehicles (UAVs) in numerous industrial and military operations around the world. UAVs are often deployed for missions that are too "dull, dirty, or dangerous" for manned aircraft [1]. As part of mission planning, path planning technologies will play a pivotal role to improve viability and mission ability of UAVs. Usually, path planning refers to a "point-to-point" mission whose solution determines a path between start and goal points [2]. However, when the position of a reconnaissance target is uncertain or when the point of interest concerns the information of a certain area, the region Coverage Path Planning (CPP) should be carried out. The region coverage is defined as the sensor footprint covering all the points in a given area [3]. The CPP applications of UAVs mainly include security monitoring, battlefield surveillance, target search, terrain mapping, mineral exploration, etc.

In recent years, CPP researches have focused on ground-based vehicles. Although some techniques are effective for ground-based vehicles, they may not be applicable directly to UAVs since the coverage paths of ground-based vehicles allow more turns [4–7]. UAVs should reduce the number of turns because route length, duration and energy consumption will increase with increasing number of turns (This claim will be proved in Section 2).

The author of [8] has shown that several existing algorithms which are called exact cellular decomposition take the following basic approach in generating a coverage path. Firstly, the region to be covered is decomposed into subregions. Next, a traveling-salesman algorithm is applied to generate a sequence of subregions to visit and in turn a coverage path is generated from this sequence that covers each subregion. Finally, the subregions are individually covered using a back and forth motion which is called sweep method.

Most of the above algorithms employ the same sweep direction in all subregions which may not be able to obtain optimal results [2,9]. In addition, some of the algorithms are applicable for some specific regions only. When the region is changed, the algorithm is no longer feasible [8,10]. Moreover, to our knowledge, the problem of subregion connection, in particular, the joint-point differences of subregions, which will impact the weights of undirected graph, has not been addressed in the literatures.

Since the area to be covered is usually a polygon area, and most of the non-polygon areas can be transformed to polygon areas by polygonal approximation, this paper will focus on CPP in polygon area. Specifically, this paper presents an enhanced exact cellular decomposition method which can optimally solve the problem of CPP in the polygon area. The major contributions of this paper

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