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基于流水避石原理的无人机三维航路规划方法

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Three-dimensional Path Planning for Unmanned Aerial Vehicles Based on Principles of Stream Avoiding Obstacles

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摘要

借鉴自然界流水避石现象,提出一种基于流体计算的无人机(UAV)三维(3D)航路规划方法。首先介绍了球心位于坐标原点时,球形障碍三维绕流问题的解析解。之后采用旋转平移矩阵与流线数据叠加方法生成了任意位置多障碍同时存在的三维流线。为验证解析解的有效性同时给出该方法基于数值模拟的计算过程,对适合无人机三维航路规划的流体模型和数值求解方法进行了分析,并给出了通过数值模拟求解航路的方法。最后,根据无人机机动约束对流线进行处理得到可飞航路,将航路长度、纵向和横侧向机动次数作为子目标函数对航路进行综合评价。仿真结果表明:解析法航路规划中,圆球障碍的地形建模简单计算量小,航路集中在由起点至终点的航路带间;数值法航路规划适合障碍分布复杂的地形,航路分布于规划空间中。这两种方法的航路平滑,能够满足无人机飞行约束,航路具有绕流意义的最优性,可以避免势场法的局部极小问题,并且可以提供多条备选航路。

关键词： 无人机 三维航路规划 流体力学 无人机约束 综合评价

Abstract:

Using the principles of fluid computation, a three-dimensional (3D) path planning method for unmanned aerial vehicles (UAVs) is studied by imitating the natural phenomenon of a flowing stream avoiding obstacles. First, an analytical solution of the steady 3D ideal flow acting on a single spherical obstacle is used to imitate the movement of a UAV. Then, a rotation-translation matrix in combination with the stream data are designed to generate streamlines when there are multiple obstacles in arbitrary positions. To verify the effectiveness of the method and introduce the method of numerical simulation, the fluid model and numerical solution suitable for 3D path planning are analyzed. Finally, the streamlines that satisfy the maneuverability constraints of the UAV are selected as the flight paths. Length of the path and times of motion in longitudinal and latitudinal directions are chosen as sub-objective functions to make a comprehensive evaluation. Simulation results demonstrate that in analytical paths, the model of spherical obstacles will reduce computation, and paths distribute in a ribbon from the starting to the finishing area; the numerical paths can deal with complex terrain, and paths distribute in a planned space. Both methods based on fluid flow can avoid local minima of a potential field, satisfy UAV constraints and provide multiple alternative paths. In addition, the paths are smooth and have the optimal characteristic of flow around obstacles.

Keywords: unmanned aerial vehicles three-dimensional path planning fluid mechanics maneuverability constraints of UAV comprehensive evaluation

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