

# 持续监视问题多无人机协同搜索策略\*

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**摘 要:**针对持续监视问题开展多无人机协同搜索策略研究。将模糊数学理论引入协同搜索领域,提出了基于模糊c均值聚类的多无人机协同搜索策略,克服了常见多无人机协同搜索策略由于重复搜索与频繁转场导致搜索代价无功消耗的不足。在此基础上考虑无人机动力学约束,以提高搜索策略的工程实用性。最后,通过数值仿真对FCM搜索策略进行效能分析。仿真结果表明,与常见多无人机协同搜索策略相比,该策略具有搜索效率高与稳定性强的优势。

**关键词:**持续监视问题;多无人机;协同搜索;模糊聚类

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## Cooperative Search Strategy for Multiple UAVs Based on Fuzzy c-Mean Cluster

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**Abstract:** Cooperative search strategy for multiple UAVs was studied for the persistent surveillance problem. Through adopting the theory of fuzzy mathematics in the field of cooperative search, the cooperative search strategy for multiple UAVs based on fuzzy c-mean cluster (FCM) was proposed. The newly developed strategy overcomes the shortage of the useless search cost resulted from repeated searching and frequently transiting from one cell to another. Additionally, the UAV's dynamics constraint was considered to improve the practicality of the FCM strategy. The performance of the FCM strategy was analyzed through numerical simulations. The results show that the FCM strategy has the advantages of high efficiency and excellent stability.

**Keywords:** persistent surveillance problem; multiple UAVs; cooperative search; fuzzy cluster

### 0 引言

无人机对目标空间执行持续监视任务<sup>[1]</sup>广泛应用于气象监测、地形测绘、战术侦察和地外探索等领域<sup>[2]</sup>,典型的侦察无人机包括“全球鹰(Global Hawk)”、“捕食者(Predator)”和“折叠式扫描鹰(ScanEagle Compressed Carriage, SECC)”等。然而,在现实任务环境中,由于持续监视任务的复杂性和多样性,单架无人机独立完成持续监视任务变得十分艰难,因此多无人机协同搜索成为一种有效的解决方案<sup>[3-4]</sup>。多无人机协同搜索策略研究正逐渐成为研究热点。

本研究从持续监视问题的基本概念入手,针对贪婪搜索策略和分布式协议搜索策略两种基准策略<sup>[5]</sup>在执行持续监视任务时因重复搜索和频繁转场导致搜索代价无功消耗的不足,将模糊聚类方法引入协同

搜索策略,提出了基于模糊c均值聚类的多无人机协同搜索策略(FCM搜索策略)。仿真结果表明,FCM搜索策略具有搜索效率高与稳定性强的优点。

### 1 持续监视问题描述

持续监视问题可描述为对某一群体或地点保持密切观察。对敌军进行频繁照相是持续监视问题的经典应用。持续监视问题要求对目标空间长时间频繁甚至连续不断的进行观察覆盖,使得对目标空间内不同区域进行两次搜索的时间间隔最短。持续监视问题相对于其它搜索问题,是一种更为复杂的搜索问题。其特点是目标在搜索空间出现的位置与时间均未知且不确定,要求对所有单元格持续均匀的进行搜索。为研究搜索策略方便,将持续监视问题作如下简化:

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