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DISTRIBUTED SENSOR TASKING METHOD FOR SEARCHING AND TRACKING CISLUNAR SPACE OBJECTS

Abstract

In recent years, the growing demand for Lunar resource exploration has led to an increase in Cislunar missions. However, the lack of comprehensive awareness of Cislunar space objects poses collision risks to mission safety, underscoring the need for enhanced Cislunar Space Situational Awareness (SSA). Given the vastness of Cislunar space and the limited availability of Cislunar space-based sensor resources, this paper focuses on developing an adaptive multi-sensor tasking method to address the challenges of new target search and catalog maintenance within Cislunar space.

To address the diversity of Cislunar orbits and the dispersive distribution of Cislunar space objects, a space-based surveillance network is first designed to provide advanced SSA capability for Cislunar space. The orbit deployment and optical sensor configurations of the network are designed and optimized using the NSGA-II algorithm, balancing multiple criteria, including coverage, detection capability, and cost.

Given the optimized sensor network, a distributed coordinated multi-sensor tasking method is proposed to address the complex dynamics of Cislunar space and the high uncertainty of Cislunar space objects. The method dynamically assigns multiple sensors to search or tracking tasks based on the measure of orbital uncertainty. To resolve conflicts of tasking solutions in the distributed network, an assignment matrix is established to model the cost of tasking solutions, and the consensus-based auction algorithm is introduced to facilitate information exchange among neighboring sensors and allocate high-uncertainty objects to specific sensors for tracking, while idle sensors perform search tasks, to optimize the utilization of Cislunar space-based sensor resources.

For search task, sensors are scheduled to sequentially scan their Field of Regard (FOR) to search for unknown targets, and the FOR is divided into a set of grids based on sensor field-of-view. If a new target is detected, the constrained admissible region is applied to determine initial orbit based on short observation arcs, which can then be added to the catalog database. For tracking task, the sensor's pointing direction is determined by maximizing the Rényi information gain, and the Labeled Multi-Bernoulli filter is employed to recursively estimate orbital states of cataloged objects, ensuring stable catalog maintenance.

Simulations are conducted to validate the proposed distributed sensor tasking method, and the results demonstrate its effectiveness in achieving robust orbit and cardinality estimation. By optimizing the

utilization of limited sensor resources and ensuring efficient task allocation, the proposed method lays a solid foundation for enhancing Cislunar SSA and ensuring the safety of Cislunar missions.