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GRID-FREE SENSOR TASKING FOR SPACE SURVEILLANCE CONSIDERING REPOSITIONING LATENCY

Abstract

The rapid advancement of space technology has exponentially increased the number of deployed satellites, significantly raising the risk of collisions. Given the limited sensors to track this growing population, an effective tasking method is critical for catalog maintenance accuracy. Typical sensor tasking methods discretize the sensor's Field of Regard (FoR) into grids, greedily selecting cells with maximal information gain at each step. This approach induces two flaws: the rigid grid-based optimization traps systems in local optima, while the inherent discretization prevents precise modeling of telescope lens motion, thereby ignoring repositioning latency. Furthermore, incorporating latency introduces conflicts between time constraints and traditional information gain objectives, significantly increasing the complexity of the optimization problem.

To address these challenges, this paper proposes a grid-free sensor tasking method that optimally allocates surveillance sensors for observation, considering the target state and repositioning latency. To achieve this, a possibilistic Interacting Multiple Model Labeled Multi-Bernoulli (IMM LMB) filter is developed to track a large number of targets involving maneuvers using the Outer Probability Measure (OPM) framework. Then, an overall objective function is formulated by integrating repositioning latency and the information gain derived from pseudo observation. This objective function serves as a guiding mechanism for the system to determine the optimal tasking solution, effectively striking a balance between minimizing time consumption and maximizing the reward acquired. Subsequently, the grid-free sensor tasking problem is modeled as a sliding window optimization problem, aiming to identify the window, i.e., Field of View (FoV), that maximizes the summed objective function for the covered targets. The candidate sliding window is selected exclusively based on target positions within the FoR, ensuring computational efficiency. For targets with uncertain presence in the FoV, the objective function is adjusted according to the detection possibility derived from the state uncertainty described by the OPM theory.

A simulation case is designed to evaluate the feasibility of the proposed method. The experiment simulates a scenario in which 4 space-based sensors are tasked with detecting the Starlink constellation, consisting of 1,000 non-maneuvering targets and 5 maneuvering targets equipped with electric propulsion in 4 hours. Results demonstrate that the proposed grid-free sensor tasking method accurately maintains the state of all targets and outperforms the traditional grid-based approach, suggesting its practicability for addressing sensor tasking challenges in large-scale space surveillance.