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Author: Ms. Jiaxin Hao
Beijing Institute of Technology (BIT), China

Dr. Han Cai
Beijing Institute of Technology, China
Mr. Chenbao Xue
Beijing Institute of Technology (BIT), China
Prof. Jingrui Zhang
Beijing Institute of Technology, China

ADAPTIVE SENSOR TASKING FOR COLLISION ASSESSMENT UNDER EPISTEMIC UNCERTAINTY

Abstract

With the continuous development of the space industry, the increasing number of space objects poses a growing collision risk to space assets. Given limited space surveillance sensor resources, it is essential to develop an adaptive sensor tasking method capable of simultaneously tracking multiple targets and assessing collisions. Nevertheless, traditional probabilistic Random Finite Set (RFS) based sensor tasking and multi-target tracking algorithm solely account for aleatory uncertainty. This oversight of epistemic uncertainty can lead to the probability dilution effect in collision assessment, where a large covariance results in a near-zero collision probability, reflecting a lack of knowledge rather than confirming non-collision. Thereby, it is crucial to develop a sensor tasking method that incorporates a more comprehensive uncertainty characterization to achieve more accurate collision assessment.

To address these challenges, this paper proposes an adaptive sensor tasking method that identifies targets with different collision risk levels and autonomously allocates more surveillance resources to the higher-risk targets in multi-target tracking scenario. This method integrates sensor tasking, guided by collision information, into a possibilistic Labeled Multi-Bernoulli (LMB) filter within an Outer Probability Measure (OPM) framework. An augmented LMB Uncertain Finite Set (UFS) is employed to characterize the collision risk alongside trajectory-related parameters. The collision risk level is determined by the upper and lower bound of collision probability assessed using OPMs. The crux of the sensor tasking problem lies in its objective function, which incorporates the collision risk level into a possibilistic information divergence, following the principle of maximizing the information gain to determine the optimal tasking solution at each time step. The collision risk level for each target dynamically adjusts as the epistemic uncertainty decreases due to more frequent observations and information fusion across the sensor network. The proposed method enables robust tracking performance and collision assessment that align more closely with real-world scenarios through the integration of multi-sensor tasking, multi-target tracking and information fusion.

To validate the performance of the proposed method, a simulation scenario is constructed involving 24 space-based sensors tracking 1000 LEO targets alongside 10 pairs of targets assumed to experience collision events during the tracking period and tested under different uncertainty levels. Results demonstrate that the developed method is superior in yielding accurate state estimations and enhanced collision assessment, highlighting its feasibility and flexibility to address sensor tasking problem accounting for targets' collision-related information.