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SPACE DEBRIS: DETECTION & CLASSIFICATION - AND FILTER DEVELOPMENT FOR LIVE EXPERIMENTATION

Abstract

The growing accumulation of space debris presents a significant challenge to satellite operations and future space missions, necessitating the development of efficient debris detection and mitigation strategies. In this study, Two-Line Element (TLE) data related to the orbital positions, velocities, and angular momentum of satellites and debris are extracted for analysis. To enable precise debris identification, a heuristic algorithm-based machine learning (ML) model is proposed. This model prioritizes debris fragments for retrieval based on criteria such as size, trajectory, and collision risk, while deprioritizing those requiring lower urgency.

To validate the effectiveness of the proposed ML model, it is integrated with an optical sensor to perform real-time debris detection. The system is deployed on ISRO's PSLV Orbital Experimental Module (POEM) platform, enabling live testing in actual orbital conditions. The hybrid ML model-optical sensor configuration enhances detection accuracy and enables real-time classification of debris by analyzing trajectory, size, and rotational dynamics. The real-time validation of the proposed methodology, supported by an experimental setup, represents a significant step toward autonomous debris identification in space, offering an intelligent solution for debris removal and sustainable space operations. To further verify the system's reliability, the authors will develop a hardware-in-the-loop (HIL) system for end-to-end testing of the debris detection and prioritization workflow. The findings of this study contribute to global efforts to mitigate collision risks and ensure sustainable space operations. Future work will focus on refining the ML model, optimizing debris collection mechanisms, and expanding real-world testing through additional orbital missions.

Keywords: Heuristic algorithm-based machine learning; Real-time debris classification, optical sensor integration, sustainable space operation