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AI-ENHANCED ELECTRO-OPTICAL SENSING: SINGLE-SATELLITE APPROACH TO SUB-CENTIMETER DEBRIS DETECTION

Abstract

Space debris smaller than ten centimeters poses a considerable hazard to orbital assets, yet remains notoriously difficult to detect and characterize using conventional approaches. In this work, we introduce an AI-driven small debris detection technique that harnesses an advanced camera array on a single satellite platform. Our method integrates high-sensitivity electro-optical imagers with robust, deep-learning models to isolate faint streaks of millimeter- to centimeter-scale debris against the star-filled background.

The proposed approach addresses the inherently low signal-to-noise ratio of small debris observations by combining physics-based noise modeling (encompassing shot noise, dark current, and readout noise) with adaptive deep neural networks. The resulting pipeline continuously filters out spurious detections and enhances debris targets in near-real time. By fusing data from multiple cameras onboard the satellite and applying new algorithms, we refine short-arc measurements into accurate orbit estimates.

Simulation results demonstrate the system's ability to reliably detect and track previously overlooked debris fragments, significantly improving orbital safety insights and collision-risk assessments. This single-platform solution offers an efficient, scalable framework for future space missions tasked with maintaining a safer and more sustainable orbital environment