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SMALLSAT-BASED NEAR-EARTH OBJECT (NEO) DETECTION USING TRANSFORMER AI MODEL FOR IMPROVED PLANETARY DEFENSE

Abstract

Near-Earth Object (NEO) detection plays an indispensable role in planetary defense. Substantial advancements in NEO detection owe much to ground-based projects such as the *Minor Planet Center* (MPC), *Center for NEO Studies* (CNEOS), and *Asteroid Terrestrial-Impact Last Alert System* (ATLAS). Significant progress in NEO detection has been made in recent years and the upcoming *NEO Surveyor* mission in 2028 – designed to detect more than 90% of NEOs 140 meters or larger – will roughly triple our current capability.

Nonetheless, a critical void persists in our capacity to detect objects smaller than 140 meters. An estimated 230,000 or more objects, equal to or larger than 50 meters, pose potential threats to concentrated regions and urban areas, with fewer than 8% currently identified. According to the *NASA Planetary Defense Strategy and Action Plan 2023*, a comprehensive NEO survey catalog and robust characterization capabilities are exigent for discerning and addressing potential impact threats. There is an urgent global imperative for a thorough NEO survey catalog coupled with robust characterization capabilities.

To address this, we propose a SmallSat-based NEO detection system utilizing a Transformer-based AI model for autonomous processing of satellite imagery. Transformers, known for their success in Natural Language Processing (NLP), have demonstrated remarkable effectiveness in computer vision tasks, making them well-suited for analyzing the complex, sequential data inherent in satellite observations. Their parallel processing capability facilitates a nuanced understanding of temporal dynamics, crucial for detecting subtle changes in time-series images. Additionally, their efficiency in handling large data volumes combined with the self-attention mechanism allows them to identify intricate patterns and correlations within the vast and diverse satellite data. This is particularly advantageous in astronomy, where precise detection and monitoring of transient events like NEOs necessitate the analysis of extensive image sequences. To ensure high reliability and relevance, we use training datasets that closely resemble the actual observations the SmallSat will collect.

This paper presents the design of the SmallSat detection system, including its subsystems (structure, power, command data handling, communication, attitude control, thermal control, and payload). We also detail the AI model trained using open-source data from existing ground-based systems. This work aims to demonstrate the powerful integration of AI into SmallSats for early NEO detection and characterization, paving the way for stronger planetary defense and space situational awareness, and offering a critical window for informed decision-making and mitigation strategies to potentially prevent future impacts.