

19th IAA SYMPOSIUM ON SPACE DEBRIS (A6)
Operations in Space Debris Environment, Situational Awareness - SSA (7)

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TOWARDS GRAPH REPRESENTATION LEARNING FOR CONJUNCTION ASSESSMENT

Abstract

The prevention of in-orbit collisions is crucial both in the near-term, to protect current-day space assets, and for long-term space sustainability. To this end, identifying close approaches between all catalogued objects, whether active or debris, is of vital importance for early detection of potentially catastrophic events. However, this problem of *all versus all* conjunction assessment is computationally challenging, with hundreds of millions of possible conjunction pairs already present today, and threatens to become ever-more so in the face of increasing space traffic and observational capabilities in the New Space era. With a pressing need to look for new solutions to this problem, one emerging approach is the adoption of recent advancements in the field of machine learning [1].

In the all versus all case, interactions (links, or edges) between pairs of individual objects (nodes) over a whole catalogue can be naturally described using a graph. Graph-structured data such as this is prevalent in a wide variety of different domains, from social networks, to transport networks, to molecular graphs. Following the successes of Graph Neural Networks (GNNs) in these areas, the application of machine learning to graph-structured data has become one of the fastest growing research areas in machine learning. Unlike for grid-like data, such as sequences or images, which have a standard data representation, one of the main challenges in this domain is to build a representation of the graph that can be successfully exploited for downstream tasks such as link prediction (e.g., recommending new social network connections, or predicting collisions between two space objects).

In this work, we present a graph-based, global representation of the all versus all scenario that is able to profit from recent advancements in Graph Representation Learning, and make a step towards efficient, machine learning based conjunction assessment without the need to iterate over object pairs. For this, we employ a realistic dataset, composed of TLE data and conjunctions generated using the CNES BAS3E space surveillance simulation framework [2]. Focusing on the downstream task of conjunction screening, we investigate the suitability of different data representations and graph constructions for this task, considering key aspects such as graph sparsity, which is of particular interest due to the significant variation in object density between altitude bands, as well as scalability.

[1] E. Stevenson et al., Artificial Intelligence for All vs. All Conjunction Screening, 8th European Conference on Space Debris, 2021.

[2] V. Morand et al., BAS3E: A Framework to Conceive, Design, and Validate Present and Future SST Architectures, 1st NASA International Orbital Debris Conference, 2019.