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Space Debris Detection, Tracking and Characterization - SST (1)

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IMPROVING BALLISTIC COEFFICIENT ESTIMATION OF RESIDENT SPACE OBJECTS IN LOW EARTH ORBIT

Abstract

Characterizing Resident Space Objects (RSO) is fundamental for several Space Situational Awareness functions, such as accurate orbit prediction and collision avoidance. The main non-conservative orbital perturbation that acts on RSOs in Low Earth Orbit (LEO) is the atmospheric drag, that can be predicted with significant uncertainty. In fact, it strongly depends on the atmospheric density and the solar activity, which have a stochastic nature, and on some physical characteristics of the RSO, which are either unknown or known with limited accuracy for space debris. Among these features, an important role is played by the ballistic coefficient (BC), i.e., the product between the drag coefficient (Cd) and the area-to-mass ratio (AMR). Current literature proposes several approaches to estimate either the single term that constitute the BC, e.g., (Ray et al., 2020) for the Cd, (Linares et al., 2014) and (Lacruz et al., 2020) for the AMR, or the whole parameter as in (Pilinski et al., 2016) and (Cimmino et al., 2023). In particular, lately an increasing number of works are based on Machine Learning (ML) and data driven techniques (Peng and Bai, 2018)-(Cimmino et al., 2023), due to the computational cost advantage of such algorithms. Most of these works, either assume that the ballistic coefficient is constant over the time interval of the analysis or estimate a mean value. However, the BC of a space object can vary significantly over a certain time interval, especially for space objects for which the combination of shape and attitude dynamics determine a significant time variation of their cross section, which has a non-negligible impact on the orbital trajectory. In this context, this paper provides two main contributions. First, it proposes a reduced set of features to train Neural Networks for ML-based ballistic coefficient estimation of RSOs, while also introducing an original pre-processing technique to filter the astrometric data received in input by the trained network, thus removing undesired oscillations. Secondly, the potential of several approaches, both conventional and ML-based, to detect ballistic coefficient variation for space objects in Low Earth Orbit is investigated. A sensitivity analysis is conducted to assess the minimum variation of the BC that can be detected for a fixed time interval, as well as the minimum time needed to detect a certain BC variation. The applicability of the presented approaches is tested and discussed using both real (i.e., based on publicly available catalogues of Two-Line Elements) and synthetic datasets.