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RECURRENT NEURAL NETWORKS FOR RESIDENT SPACE OBJECTS CHARACTERIZATION IN MEO AND GEO

Abstract

Resident Space Objects (RSOs) characterization is a key activity to support several Space Situational Awareness functions, such as accurate orbit prediction and collision avoidance. The main non-conservative perturbation acting on RSOs in Medium Earth Orbit (MEO) and Geostationary Earth Orbit (GEO) regions is the Solar Radiation Pressure that can be estimated with significant uncertainty. In fact, it strongly depends on the solar activity, which has a stochastic nature, and on physical characteristics of the RSO, which are either unknown or known with limited accuracy for space debris. A critical role is played by the radiation ballistic coefficient (BCr), i.e., the product between the reflectivity coefficient (Cr) and the area-to-mass ratio (AMR), i.e., the ratio between the area exposed to the Sun and the mass of the RSO. Current literature proposes several approaches to estimate either the BCr or the single terms constituting it. Many techniques rely on photometric data, i.e., light curves. However, the intricate relationship between the object's properties, the observation geometry, and the noise sources can make the light curve inversion process a non-trivial and computationally expensive operation. Astrometric data, which provide the state vector of a RSO, can integrate the characterization based on photometric data, leveraging the time evolution of the orbital parameters. In particular, previous works have demonstrated the applicability of Machine Learning techniques to characterize RSOs in Low Earth Orbit (LEO) using this type of data. In this context, this paper investigates the applicability of Recurrent Neural Networks (RNNs) to estimate the BCr of RSOs in MEO and GEO, exploiting only astrometric data, thus extending state-of-the-art approaches applied in LEO to other orbital regimes. Unlike feedforward neural networks, RNNs are optimised for time-series data, harnessing the underlying information in the time evolution of the orbital parameters, thus allowing for a reduced number of input data. A simulation environment, conceived to generate synthetic datasets thanks to a high-fidelity numerical orbital propagator, is used for neural network training, validation and testing. A hyperparameters tuning and a features selection process are performed to design the RNN architecture. A sensitivity analysis is carried out to assess the impact on performance of the propagation time and the measurements frequency. Moreover, analyses are carried out to evaluate the robustness against measurement noise in the input data, and considering a

time-varying data sampling step. The applicability of the presented approach is finally evaluated using real data from open-source catalogues.