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Author: Dr. Xiaoli Bai
Rutgers University, United States

Dr. Hao Peng
Rutgers, The State University of New Jersey, United States
Dr. Lesley Weitz
The MITRE Corporation, United States
Dr. Scott Kordella
The MITRE Corporation, United States

ENHANCE THE TLE CATALOG THROUGH SHARING MACHINE LEARNING MODELS

Abstract

We have recently developed a methodology to predict trajectories of resident space objects (RSOs) with higher accuracy than the current methods. Inspired by the machine learning (ML) technologies, our proposed method leverages state-of-the-art physics models which are accurate and uses ML methods to provide other necessary details that are unresolved theoretically. Methods including support vector machine, artificial neural network, and Gaussian processes have been explored and showed effective. We have also validated our physics-based learning strategy using real data from the Two-Line Element (TLE) catalog and International Laser Ranging Service catalog.

As an important next step towards establishing an information sharing capability, this paper studies two aspects of enhancing the TLE catalog through sharing the ML models. First, we propose a service mechanism to publish the learned ML models to the community. The training, testing, and evaluation of the ML models require learning from a regularly updated dataset. However, for the end-users, it is not necessary to acquire this dataset. The ML model can be fully represented by its structure and learned parameters, which the agent in charge of the catalog maintenance can distribute to the community as a service. A related, important issue is that the trained ML models need to be examined by a monitoring system before its distribution, due to the statistical nature of the ML methods. The service shall also quantify the prediction uncertainty about the learned ML models. In essence, the proposed improvement to the TLE catalog is an "ML model database" corresponding to each RSO in the TLE catalog. This augmentation will not interfere with the existing procedures for TLE catalog maintenance, but provide an independent modification to the predictions generated using the current procedure. In practice, the proposed TLE upgrade can be smoothly transitioned from using the current TLE predictions to using ML-enhanced TLE predictions by running and comparing both procedures in parallel.

Second, we will investigate the potential to further improve the TLE accuracy by launching specifically designed calibration satellites, which should be tracked by high-accuracy approaches like laser ranging. This is inspired by our earlier studies which have shown that the ML model based on a RSO can be applied to other RSOs that share some common features. After categorizing the RSOs into different groups, the generalization capability of the trained ML models among the same group of RSOs will be examined to demonstrate the possibility of developing a calibration satellite.