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RECOVERING AREA-TO-MASS RATIO INFORMATION OF GEOSYNCHRONOUS OBJECTS FROM HISTORICAL ORBITAL INFORMATION

Abstract

High area-to-mass ratio (HAMR) resident space objects (RSOs) in GEO are a recently discovered hazard to GEO satellites as they cross the same region. Their AMR can be as high as 20 m^2/kg but are difficult to be accurately measured and estimated due to limited tracking capabilities. Consequently, non-conservative shape-dependent forces cannot be accurately calculated, leading to that the orbit prediction result is not accurate enough for precise conjunction analysis. Many studies have focused on estimating AMR by using more accurate force or shape models. Other studies focus on quantifying the prediction accuracy or studying debris' long-term evolution. In these studies, although the orbit prediction error and uncertainty are meant to be reduced, they have not made the most of historical data.

In this paper, an RSO's historical orbit prediction error is directly used as the input information, then the proposed machine learning (ML) approach learns to recover the AMR information hidden in the data. The hypothesis is that if one RSO is tracked by the same ground stations and estimated using the same force model, its orbit predictions may show consistent features, whereas RSOs with different AMR will show different features. These features can be dynamical and thus difficult to be accurately modeled. However, a data-driven ML model may be capable of extracting features from big dataset.

In the paper, simulations will be carried out using a number of RSOs around GEO with different AMRs. The right ascension and declination are measured by ground stations. The orbit determination process generates estimates of the RSO at different epochs with assumed spherical shape. Then the consistency errors between estimates are chosen as the input learning variables for the ML approach and the AMR is the desired target variable. The random forest model is chosen as the specific ML algorithm to solve the problem. It proves to be effective in our previous study for the LEO objects. The difference in this paper is that the solar radiation pressure is the dominant non-conservative perturbation. We note that the extraction of AMR information will be addressed as both a discrete classification problem and a continuous regression problem.

The result in this paper will demonstrate that the AMR information for HAMR objects can be recovered from historical data, which is a novel and effective approach. Different factors' effect on the problem will be explored, including RSO's rotational rates and sparse noisy measurements on GEO objects.