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GENERALIZED PRECISE ORBIT PREDICTION OF LEO SATELLITES VIA PHYSICS INFORMED MACHINE LEARNING

Abstract

As spacecraft missions have become more complex in recent years, autonomous spacecraft control has become increasingly important. In this study, we focus on a precise autonomous orbit prediction of LEO (Low-Earth Orbit) satellite. If satellites could autonomously predict their orbits accurately while in orbit,the observation performances will be better in accuracy and/or the maintenance operation costs can be reduced as the ground operations to update the orbital parameters can be less frequent. This paper builds on our previous study, in which our physics informed machine learning (PIML) model enables 10^4 times faster orbit prediction, and proposes a precise orbit prediction of LEO satellite via newly proposed domain generalization framework which attempts to generalize the prediction model by using actual satellite data and data from various orbit conditions.

In conventional method, orbit prediction for satellites in orbit was performed using a simple algorithm based on the two-body problem, so the prediction accuracy is low and frequent parameter updates by ground operation are required to keep the accuracy of onboard orbit prediction. In this paper, we propose the use of a surrogate PIML model trained based on domain generalization, where we train our model on numerical simulation data and test on real data to test generalization capability. The proposed PIML algorithm is based on modelling physics system such as Ordinary Differential Equation (ODE) with deep neural networks, which through an end-to-end training could allow for capturing unknown physical phenomenon and generalizing to different tasks such as orbit prediction of spacecraft orbiting around asteroids. The proposed method is expected to reduce the ground operation cost drastically and realize an onboard orbit prediction. We also analyze the effect of use of real data in training our model to evaluate its potential use for satellite onboard operation. The simulation results show that the proposed method enables high accuracy in orbit prediction based on the assumed onboard computing performances.