Paper ID: 77075
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IAF ASTRODYNAMICS SYMPOSIUM (C1)
Orbital Dynamics (1) (8)

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# PRECISE ORBIT PREDICTION OF LEO SATELLITE VIA PHYSICS INFORMED MACHINE LEARNING

**Abstract**

In recent space missions, the more complicated the missions become, the more important autonomous spacecraft controllers are. In this study, we focus on a precise autonomous orbit prediction of LEO (Low-Earth Orbit) satellite. If a satellite could precisely predict its own orbit autonomously 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 proposes a precise orbit prediction of LEO satellite via physics informed machine learning.

In conventional method, the orbit prediction is executed autonomously in-orbit using a simple algorithm based on 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. The proposed method is expected to realize a more accurate onboard orbit prediction using the satellite position and velocity data provided from GPSR installed on the satellite. In this paper, we constructed a surrogate model using physics informed machine learning which is trained on historical in-orbit GPSR data of an actual satellite and/or numerical simulation and evaluated the expected orbit prediction accuracy assuming computing performances of next-generation space vector computer. The physics informed machine learning enables us to predict the satellite orbit with compatible accuracy to the numerical simulation but more efficiently. The proposed physics informed machine learning algorithm is based on modelling Ordinary Differential Equation (ODE) using deep neural networks, so that hidden dynamic or unmodelled physical phenomenon could be captured using end to end training. Physics informed machine learning has been applied in various natural science fields, showing the ability to accelerate the computation of solution of ODEs and PDEs (Partial Differential Equations) or to capture model mismatch, thus improving accuracy of open-loop prediction and generalization ability, for example when applied to the control of instable inverse pendulum or quadcopter. We also analyze the limitations in terms of prediction errors with respect to noisy measurements and jitter, and computational requirements for satellite onboard operation.

The simulation results show that the proposed method enables higher accuracy in orbit prediction based on the assumed onboard computing performances.