16th IAA SYMPOSIUM ON SPACE DEBRIS (A6)
Operations in Space Debris Environment, Situational Awareness (7)

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COMPARISON OF EFFECTIVE MACHINE LEARNING ALGORITHMS ON IMPROVING ORBIT PREDICTION ACCURACY OF LOW EARTH OBJECTS

Abstract

Recently we have proposed a framework to use the machine learning (ML) approach to improve orbit prediction accuracy for resident space objects (RSOs) in low Earth orbit (LEO). In the proposed framework, for an orbit prediction based on a certain estimate of the RSO, an ML model trained by historical data will generate a compensation on the orbit prediction error, so that the modified orbit prediction is closer to the orbit's true location than the original prediction. Fundamentally, the ML approach aims to capture the relationships between the information available and the orbit prediction error. These relationships are often difficult to model in the practice because they depend on unknown features of the RSO (area-to-mass ratio, reflection coefficient, etc.) and unknown external forces (atmosphere drag, etc.). However, with the assumption that the relations are at least partially embedded in the historical data, state-of-art ML algorithms can be used to learn the relationship from the data.

The proposed approach can be implemented with different ML algorithms. In separated studies, we have investigated three effective ML algorithms, including support vector machine (SVM), artificial neural network (ANN), and Gaussian process regression (GPR). Under certain conditions, all the three algorithms have universal approximation capabilities for the regression problem. Although they all show good performance to improve the orbit prediction accuracy, each method has its unique characteristics. In short, the SVM is a sparse algorithm with a guaranteed unique solution due to its convex property; the ANN is flexible and can be easily trained online; and the GPR can provide additional uncertainty information about its output due to its Bayesian feature. On the other hand, they all have different drawbacks as well. Therefore, it is necessary to provide guidelines on the choice of specific algorithms in the ML approach for orbit prediction applications.

In this paper, a comprehensive comparison of the three ML algorithms will be presented in a physics-based simulation environment. Discussions and guidelines on the ML approach will be provided focusing on the following aspects:

1. the performance of the ML approach with three different ML algorithms should be consistent;
2. the robustness of the method with respect to outliers in the training data will be analyzed;
3. the computational burden and efficiency to achieve comparable accuracy will be evaluated;
4. the effect of learning variables on the performance will be also investigated.