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DEEP LEARNING BASED REENTRY PREDICTION OF SPACE DEBRIS

Abstract

The trajectory modeling and re-entry prediction of space debris are challenging research areas. Many previous studies have been conducted by using orbital dynamics, optimization technique and parameter estimation. In this paper, we have proposed new approach to predict re-entry trajectory of space debris by using recurrent neural network. These deep learning models are based on LSTM(Long Short-Term Memory), GRU(Gated Recurrent Units) and Seq2Seq(Sequence-to-Sequence) method. To simplify the problem of implementing the data-driven technique with univariate time series, only the epoch and altitude information derived from the TLE(Two Line Element) data are used as the input, instead of other orbital and dynamical parameters. On the other hand, a multivariate time series has more than one time-dependent variable. Each variable not only depends on its past values but also has some relevance to other variables. This dependency is used for predicting future values of altitude. In order to construct the multivariate dataset, the first derivative of mean motion and BSTAR are added in altitude profile. After reviewing data patterns with respect to the time, the new two parameters are also fitted to have equally spaced datasets. For this goal, an exponential curve fitting is applied in the first derivative of mean motion, and the third-degree polynomial fitting function is used for BSTAR. Dataset are also normalized due to different scale for 3 parameters(min/max scaling). From the historical re-entry information of a variety of space objects, the dataset of altitude profiles is constructed using a curve fitting method to handle irregular updates of TLE data. Subsequently, Seq2Seq learning is applied to train the RNN(Recurrent Neural Network), and a data-driven model, that extracts features and knowledge from the training dataset, is generated and ready for the application. In the test phase, the developed model predicts a future trajectory of re-entry for the object of interest using the pre-processed TLE data at the beginning of the prediction. Both simulated dataset and real flight dataset were validated by comparing the predicted trajectory with ground truth data. The main results from this study can be an alternative or a supplement for enhancement of prediction accuracy for re-entered space object in the future, instead of classical physics-based re-entry prediction. We verified our strategy for uncontrolled re-entry objects including different reentry objects, and got precise prediction performance.